**A Wide-Field X-ray Probe**

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The two highest-priority large projects recommended by the New Worlds, New Horizons (NWNH) Decadal survey are WFIRST and LSST, both survey missions. Both of these projects are slated to start operations in the mid-2020s. There is no complementary X-ray survey capability planned that would match these missions in survey area and depth. While eROSITA will survey the entire X-ray sky and effectively find all massive clusters of galaxies, the ~ 30" survey-averaged PSF would preclude much of high redshift science. In order to effectively probe the growth of both supermassive black holes, particularly obscured black holes, and groups and proto-clusters at z>1, a dedicated, sensitive X-ray survey mission is required. Good angular resolution is required to give a low background for source detection, minimize source confusion, give precise source positions for identifying unique optical/IR counterparts, and distinguish point from extended sources. Here we discuss two similar wide-field X-ray mission concepts, the Wide-Field X-ray Telescope (WFXT), which was submitted to NWNH and studied in 2013 by the MSFC Advanced Concepts Office, and N-WFI, one of the three notional missions studied in the 2012 NASA X-ray Mission Concepts Study[1]. Both of these concepts have requirements of a large FoV (at least 24' for N-WFI, 1 degree for WFXT), good angular resolution (5-10" averaged over the FoV) and effective area of at least 5000 $cm^2$ at 1 keV (with a goal of 10,000 $cm^2$). N-WFI also has an effective area requirement of 1,800 $cm^2$ at 6 keV to enable Fe-K science in (nearby) AGN, resulting in a focal length of 6 m for N-WFI (the WFXT design focal length is 5 m).

Measurements of the mass and spatial distribution of clusters of galaxies to z~2, along with the spatial distribution of AGN will definitively address the *IXO* science objective, "*How does large scale structure evolve?*" By defining the luminosity function of AGN as a function of redshift (to z ~ 6), notably including obscured AGN often missed by other surveys, and determining the host galaxy properties and environment, the *N-WFI* or *WFXT* surveys will answer the *IXO* question, "*When and how did supermassive black holes grow?*" The large numbers of clusters and groups of galaxies that would be detected (~ $10^5$) with good angular resolution will reveal the role of AGN outbursts in their formation and evolution, and how this may change as a function of redshift which will address the *IXO* science objective, "*What is the connection between supermassive black hole formation and evolution of large scale structure?*"

An X-ray survey probe would also study the growth and evolution of clusters of galaxies by carrying out sensitive large-area surveys with sufficient depth to detect clusters and groups to redshifts of at least 2–3. The angular resolution of ~ *5"* will permit cluster recognition and allow the cores to be excised for measurements of cluster properties (to eliminate the possibility of spectral contamination by a central AGN). For high-z clusters, which will be detected by SZ surveys and WFIRST/LSST, X-ray observations remain critical for mass calibration and ICM physics. The detection of groups at high redshifts will inform the merger history of clusters and their growth. The impact of environment on galaxy evolution (e.g., inside or outside of clusters and groups) will be studied using the very large samples obtained in these surveys.

[1] http://pcos.gsfc.nasa.gov/studies/x-ray-probe-2013-2014.php

N-WFI or WFXT would also detect millions of AGN in medium and deep survey areas. A large number of AGN will be detected at high redshift (z > 6), although predictions vary by orders of magnitude. These X-ray surveys would place critical constraints on the total AGN population at z>6, while optical/NIR surveys will be biased towards detecting only unobscured AGN. Synergy with WFIRST (e.g., the obvious medium-depth survey area would overlap with the WFIRST HLS areas) and LSST would enable photometric and spectroscopic redshift determinations at high z. As shown in Figure 1, planned Athena WFI surveys will result in much smaller survey areas than would be needed to properly match the surveys of LSST and WFIRST.

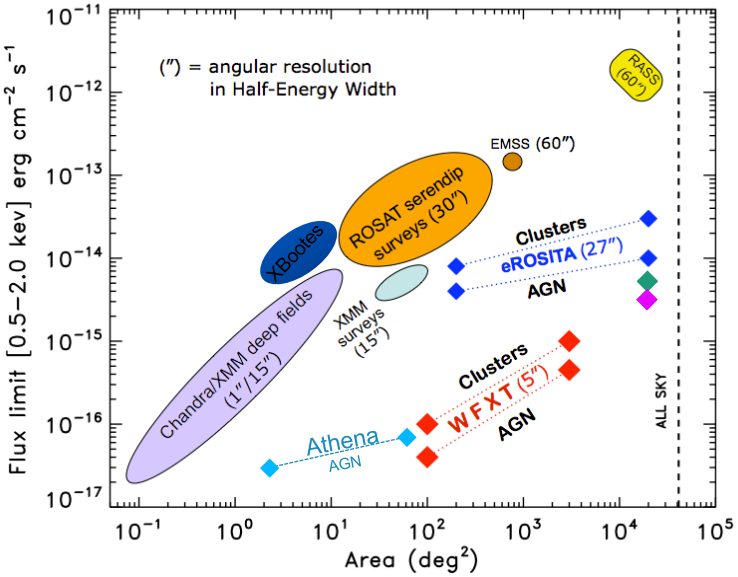


*Figure 1: Area vs flux limit for current and planned X-ray surveys, with WFXT and Athena WFI surveys also marked.*

Development in X-ray optics over the past decade has made lightweight, 5" X-ray optics a reality, and by the end of the decade one or more of the active areas of development may result in optics with an on-axis PSF of ~ 1" or better. Thus it may be possible to achieve an optical design/survey strategy with an on-axis PSF of 1-2" while maintaining a field-averaged PSF of 5-10". No other significant technology developments are needed for an X-ray survey probe mission. Advances in rapid readout technology with either traditional CCDs or active pixel sensors would improve the timing capability of the mission (most relevant in a guest observer/pointed phased of the mission) and reduce the need for optical blocking filters. Including a rapid slew capability would enable higher observing efficiency in low earth orbit and, along with a large field-of-regard, enable rapid response to targets of opportunity such as gravity wave detections and exotic LSST triggers. A large field of view, high effective area and sharp PSF would all be required to effectively acquire and monitor the EM counterpart to gravity wave sources and test competing physical models for their origin.

Both the ACO WFXT and PCOS N-WFI studies estimated costs well below $1 billion. The N-WFI cost estimate was $742M excluding launch costs ($210M was assumed for the launch). The ACO WFXT cost estimate was $541M. Mission lifetimes of 3 years (N-WFI) and 5 years (WFXT) were assumed.