爱因斯坦探针
einstein probe

EP Performance Verification (PV) Targets Recommendation Form

Submission Due Date: 15th October 2023

NOTE: Please do not change or delete the words marked in blue.

1. TITLE

Demonstrative FXT Deep Observation of the Lockman Hole and WXT Survey of the Northern High Galactic Latitude Region

2. ABSTRACT *(< 250 words)*

We propose a demonstrative deep-field survey and monitoring with a total exposure time of 60ks with FXT targeting the Lockman Hole, and the WXT field-of-view simultaneously covering the northern Galactic pole region including the Virgo and Coma clusters and several well-known AGN. The aims are to demonstrate the sensitivity of WXT and FXT with deep exposure, and also to detect new transient and highly variable sources over a range of cadences. With the lowest Galactic column density, the Lockman Hole field is one of the best studied sky areas over multiple wavebands, and also a commonly targeted field for PV observations by various X-ray satellites. Hundreds of X-ray sources detected in previous X-ray surveys make this region ideal for investigating the soft-band sensitivity of FXT. Deep FXT observations can be used to search for short-term X-ray transients and investigate intrinsic variabilities of known sources. Simultaneous observations of Virgo and Coma cluster by WXT can be used to demonstrate its enormous FoV and imaging capability for extended sources. A large number of nearby galaxies will also be monitored at a wide range of candences, enabling highly anticipated detection of TDE and other types of transients. The FoVs of FXT and WXT cover rich classes of X-ray sources, making the proposed PV program efficient and comprehensive demonstrations of EP's key performances.

3. RECOMMENDERS' INFORMATION

Principal Recommender	
***Recommender' Name**	Chichuan Jin
***Recommender' Email Address**	ccjin@nao.cas.cn
***Recommender' Expertise**	Chichuan Jin is an expert in observational study of TDEs and AGN and ISM.
***Recommender' STP(s)**	STP1
Co-Recommenders	
***Recommenders' Names**	Dongyue Li, Weimin Yuan, Haiwu Pan, Wenda Zhang, Yuan Liu, Roberto Soria
***Recommenders'**	dyli@nao.cas.cn, wmy@nao.cas.cn, panhaiwu@nao.cas.cn,

NOTE: Please do not change or delete the words marked in blue.

Email Addresses	wdzhang@nao.cas.cn, liuyuan@nao.cas.cn, rsoria@nao.cas.cn
***Recommenders' Expertise**	Weimin Yuan is an expert of the observational X-ray astronomy. Dongyue, Wenda, Haiwu and Yuan are experts in observational study of TDEs and AGNs. Roberto is an expert in X-ray study of Virgo.
***Recommenders' STP(s)**	STP1, STP3, STP4, STP5

4. TARGET FORM

- **TARGET 1** ***(mandatory)***

***Target Name**	Lockman Hole			
***Target Type**	Sky Region			
***Target Coordinates**	***RA:**	10:45:00	***DEC:**	58:00:00
***Expected Flux in 0.3-10 keV**	5.e-13 erg/cm^2/s			
***Primary Instrument**	FXT (and WXT)			
FXT Configuration ***(mandatory if the primary instrument is FXT, optional if the primary instrument is WXT)***	**FXT-A**	full-frame, thin filter	**FXT-B**	full-frame, thin filter
***Exposure Time**	60 ks			
Suggest Joint Observation with Other X-ray Telescopes				
Other remarks	targeting FXT to the center of the Lockman Hole region and covering Virgo and Coma with WXT			
*Note: * mandatory items*				

NOTE: Please do not change or delete the words marked in blue.

5. SCIENTIFIC AND TECHNICAL JUSTIFICATION
(< 2 pages in total for this session, including figures, tables and references)

- **Scientific Motivations and Values**

We propose a deep-field survey of one fixed pointing direction (exposure ~ 60ks) with FXT pointed to the Lockman Hole (LH) region whilst WXT covering the Virgo and Coma clusters and several well-known AGN. The sky coverages of FXT and WXT are shown in the left panel of Figure 1. The LH field represents the sky region of the lowest Galactic line-of-sight column density of $\mathrm{N_H} = 5.7 \times 10^{-19}\ \mathrm{cm^{-2}}$, and has been well observed by a number of X-ray telescopes (such as ROSAT, *X*MM-Newton and Chandra) as deep surveys, revealing hundreds to thousands of X-ray sources (Hasinger et al. 1998, 2001; Yang et al. 2004). It is also a sky region observed by most X-ray focusing telescopes as PV targets, such as XMM-Newton and eROSITA. It is an ideal target for comprehensive investigation of FXT's low-energy response and sensitivity, imaging quality, vignetting effect and source positioning accuracy for long exposure with data stacking of multiple observations. The sensitivity of one FXT unit can reach the order of $1 \times 10^{-14}\ \mathrm{erg/s/cm^2}$ in 0.5-2 keV with a 25-minute exposure (Yuan et al. 2022). A deep-field survey of the LH region by FXT with multiple exposures will enable comprehensive demonstration of the FXT performance, by comparison with results obtained by deep surveys of the previous missions. Science-wise, a number of pointed observations taken at a range of cadences are likely to promise detections of X-ray transients with FXT, of both short and long timescales.

One of the main science goals of EP WXT is to detect faint X-ray transients such as TDEs (Li et al. 2020; Saxton et al. 2022). To achieve this goal, the WXT detection sensitivity should reach a few times $10^{-12}\ \mathrm{erg/s/cm^2}$. This can be realized by stacking data taken from at least several-tens observations of WXT, which requires that the final resulting PSF should be comparable to that of single observation (fwhm ~5 arcmin). This requires that the positioning uncertainties of X-ray photons introduced from astrometric corrections for different observations should be much smaller than the PSF. However, this is non-trivial, given the enormous FoV of WXT; a number of factors can contribute to the uncertainties of photon stacking, including the non-uniformity of the lobster-eye MPO optics and the random variations of the pointing directions of the 12 WXT modules across the entire FoV (due to possible thermal-elastic deformation of the satellite structure). We propose to demonstrate the long-exposure sensitivity of WXT of multiple observations with a total exposure of ~60ks. Considering the vignetting effect across the FoV, it is expected that the effective exposure time would be in the range of 40-60 ks for most of the field, aiming at reaching a sensitivity of $2 \times 10^{-12}\ \mathrm{erg/s/cm^2}$ or higher based on realistic simulations. We propose the observations to be taken to cover a range of cadences from within one single observation to several days, whereby a number of transients at various timescales are expected to be detected. Of particular interest, at least one TDE is likely to be detected based on estimation of the TDE source count (right panel in Figure 1). Once a TDE is detected, FXT follow-up and possible XMM-Newton ToO observations will be triggered. There are several hundreds of known X-ray sources above $2 \times 10^{-12}\ \mathrm{erg/s/cm^2}$ within the WXT FoV in this

sky region, which can be used to test the sensitivity of WXT for different exposures over the entire FoV.

Moreover, the enormous FoV of WXT can be demonstrated by covering a number of well-separated, well-known sources of various types, including nearby galaxy clusters and AGN. The alignment of the WXT FoV is carefully designed to cover the Virgo and Coma clusters in one snapshot, whilst keeping FXT targeting the LH region. It should be noted that the Virgo cluster (Böhringer et al. 1994; Urban et al. 2011), the largest cluster in angular size, can be covered entirely in one WXT CMOS. These observations can also demonstrate the imaging capability of lobster-eye optics for extended sources with diffuse emission. A large number of nearby galaxies, either within these clusters or field galaxies, will also be monitored, which may likely result in detections of flaring objects at timescales from seconds up to days, such as X-ray binaries, ULX, and magnetars (e.g. Soria et al. 2022). The bright well-studied AGN in the proposed region include Mrk 421, 3C273, NGC 4151, some of which are also common PV phase targets of the previous X-ray missions. They are mostly detectable in a single WXT observation and can be monitored during the PV observations.

In summary, this carefully selected sky region covers a wide range of X-ray sources, and interesting results are highly anticipated from the proposed surveys with both FXT and WXT.

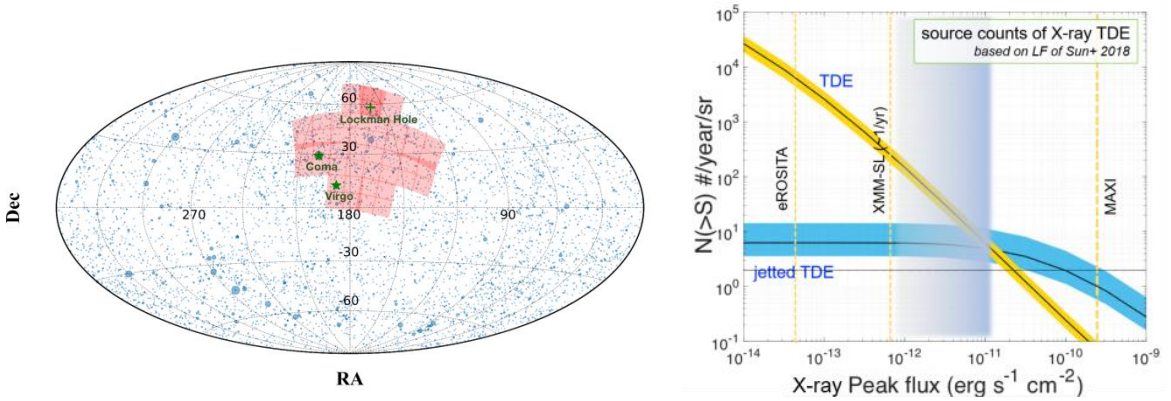

Figure 1. *left panel:* Illustration of the FoVs of WXT and FXT (red), i.e. the sky coverage of the proposed pointing observation, with the locations of the Lockman Hole region, Virgo cluster, Coma cluster in Equatorial coordinates marked. The background blue circles are 2RXS sources with flux above 2×10^{-12} erg/s/cm^2 , with the size of the circles indicate their flux level. *right panel:* Estimated event rate of X-ray TDE based on the luminosity function of Sun et al. (2015).

- **EP Capabilities to be Verified**

We would like to ask for a total exposure time of 60 ks, split into 5 epochs of observations. The observations in one epoch will be carried out in successive orbits to investigate the evolution of short-term transients. The EP capabilities that could be verified are listed below:

1) The sensitivity, imaging quality, vignetting effect and source positioning accuracy over the entire instrumental FoV for long exposure with data stacking of multiple observations, for both FXT and WXT.

NOTE: Please do not change or delete the words marked in blue.

2) FoV and imaging capability of WXT and FXT: the angular diameter of Virgo cluster is around 8 degrees. WXT will be the first X-ray focusing telescope to observe the entire region of this cluster in a single observation. Meanwhile, FXT can obtain deep energy-resolved images for the core region of LH.

3) Effective area and energy response of FXT and WXT: the observed spectra of various known bright X-ray sources, especially clusters whose X-ray emission is stable, will allow the demonstration of effective area and energy response.

- **Immediate Objectives**

(1) The FXT data can be used to detect X-ray sources with different soft X-ray fluxes in the LH region, and obtain the logN-logS distribution and compare it with abundant previous results. The data can also be used to search for e.g. extremely variable sources.

(2) The X-ray spectra of the detected sources would be used to examine FXT's response especially in soft band.

(3) To examine the WXT and FXT sensitivity at longer exposure time resulting from data stacking of multiple observations taken at different times.

(4) To demonstrate the large FoV of WXT by observe several well-known objects simultaneously in one pointing, including Virgo (the largest angular scale cluster), Coma, and a number of well-studied AGN.

(5) Both WXT and FXT data would be used to search for X-ray transients over a range of timescales from seconds to days, particularly faint transients such as TDE. once detected, FXT and XMM-Newton ToO observations will be triggered for follow-up.

- **Technical Justification (e.g. target visibility during the PV phase)**

All the proposed observations will be carried out at the fixed pointing attitude of the satellite, whose feasibility is confirmed by the EP satellite team. The Lockman Hole region is visible for EP in March 2024, so the proposed PV program should be easy to schedule.

- **References**

1. Böhringer, H., Briel, U. G., Schwarz, R. A., et al. 1994, Natur, 368, 828
2. Hasinger, G., Burg, R., Giacconi, R., et al. 1998, A&A, 329, 482
3. Hasinger, G., Altieri, B., Arnaud, M., et al. 2001, A&A, 365, L45
4. Li, D., Saxton, R., Yuan, W., et al. ApJ, 2020, 891, 121
5. Urban, O., Werner, N., Simionescu, A., Allen, S. W., & Böhringer, H. 2011, MNRAS, 414, 2101
6. Saxton, R., Komossa, S., Auchettl, K., & Jonker, P. G. 2020, SSRv, 216, 85
7. Soria, R., Kolehmainen, M., Graham, A., et al. 2022, MNRAS, 512, 3284
8. Sun, H., Zhang, B., & Li, Z. 2015, ApJ, 812, 33
9. Yang, Y., Mushotzky, R. F., Steffen, A. T., Barger, A. J., & Cowie, L. L. 2004, AJ, 128, 1501
10. Yuan W. et al. 2022, Hand book of X-ray and Gamma-ray Astrophysics
11. Zhang C.et al. 2022, ApJ, 841, L2

NOTE: Please do not change or delete the words marked in blue.