STROBE-X

X-ray Timing & Spectroscopy on Dynamical Timescales from Milliseconds to Years

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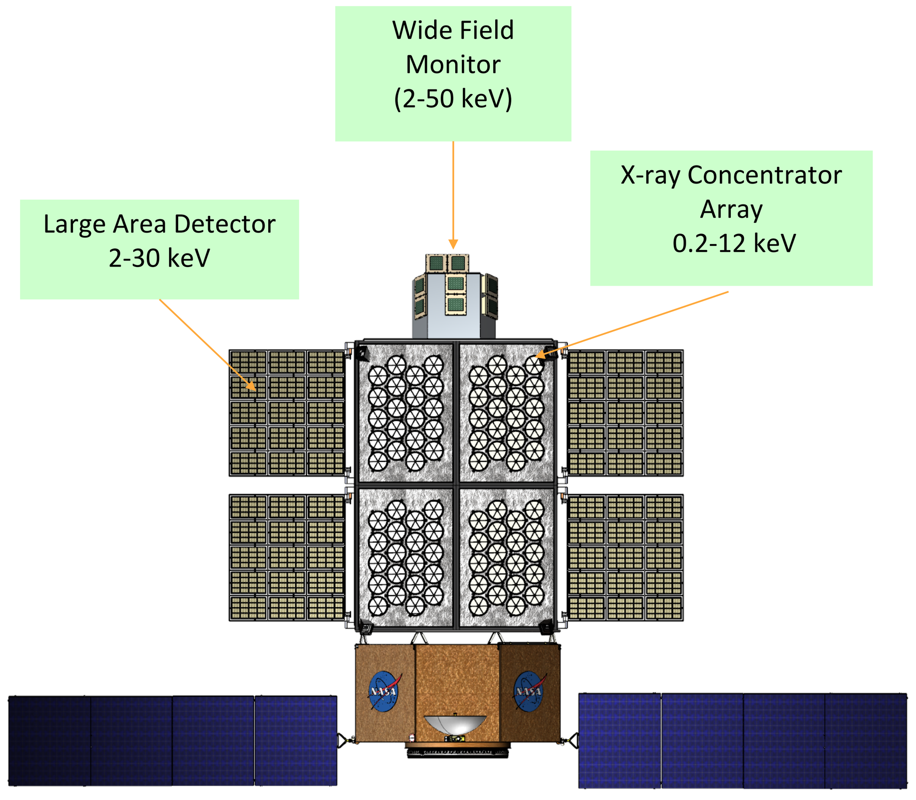
ABSTRACT: We describe a probe-class mission concept that provides an unprecedented view of the X-ray sky, performing timing and 0.2-30 keV spectroscopy over timescales from microseconds to years. The Spectroscopic Time-Resolving Observatory for Broadband Energy X-rays (STROBE-X) has three key science drivers: (1) measuring the spin distribution of accreting black holes, (2) understanding the equation of state of dense matter, and (3) exploring the properties of the precursors and electromagnetic counterparts of gravitational wave sources. To perform these science investigations, STROBE-X comprises three primary instruments. The first uses an array of lightweight optics (3-m focal length) that concentrate incident photons onto solid state detectors with CCD-level (85-130 eV) energy resolution, 100 ns time resolution, and low background rates to cover the 0.2-12 keV band. This technology is scaled up from NICER, with enhanced optics to take advantage of the longer focal length of STROBE-X. The second uses large-area collimated silicon drift detectors, developed for ESA's LOFT, to cover the 2-30 keV band. These two instruments each provide an order of magnitude improvement in effective area compared with its predecessor (NICER and RXTE, respectively). Finally, a sensitive sky monitor triggers pointed observations, provides high duty cycle, high time resolution, high spectral resolution monitoring of the X-ray sky with ~20 times the sensitivity of the RXTE ASM, and enables multi-wavelength and multi-messenger studies on a continuous, rather than scanning basis. The STROBE-X mission concept is a rapidly repointable observatory in low-Earth orbit, similar to RXTE or Swift, and will be presented to the 2020 Astrophysics Decadal Survey for consideration as a probe-class mission.

Mission Overview

The Spectroscopic Time-Resolving Observatory for Broadband X-rays



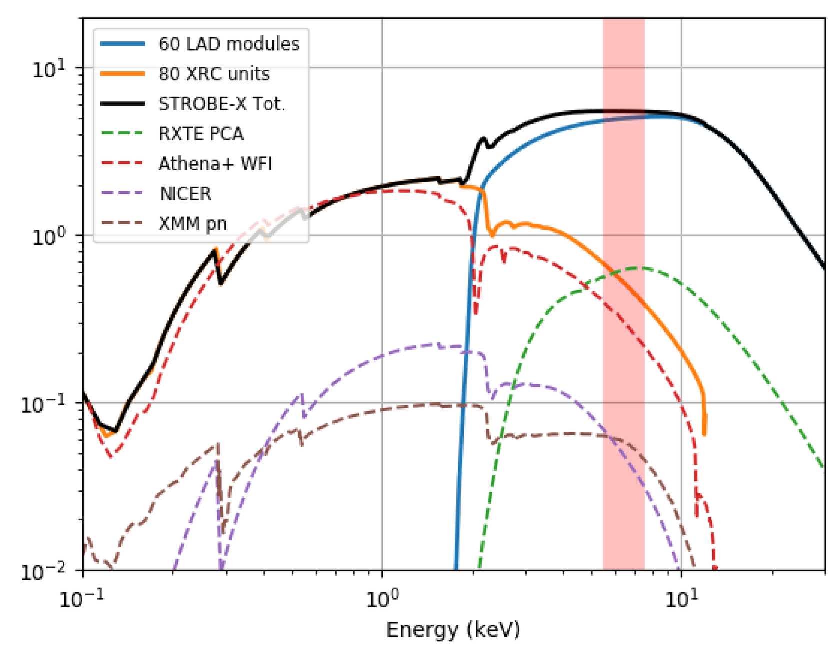


Figure 1: (Left) Notional deployed configuration of the STROBE-X spacecraft. (Right) Effective area for the current baseline configuration of 60 Large Area Detector (LAD) modules and 80 X-ray Concentrator (XRC) units. This configuration has ~5.5m^2 of effective area in the critical iron line region.

INSTRUMENTS: X-ray Concentrator Array (XRCA)

- Low background, low cost, light weight single bounce foil concentrators developed for NICER. Much simpler and cheaper than traditional X-ray optics
- Focal length 3 m with 2' focal spots for enhanced throughput >2.5 keV (relative to NICER). Set of 107 nested foil shells with diameters between 3 and 28 cm
- Energy range: 0.2-12 keV
- Energy resolution: 85-175 eV FWHM
- Effective area @1.5 keV: 2 m^2 (80 XRC units, >10×XMM, >10×NICER)
- Time resolution: 100ns

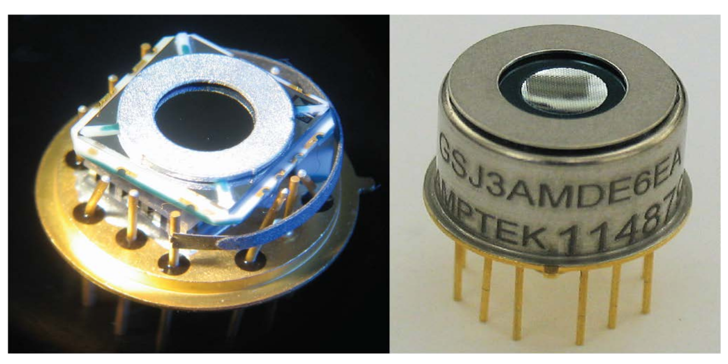


Figure 2: (Left) XACT (larger, [3]) and NICER (smaller) X-ray concentrator optics. STROBE-X XRCs will have approximately the diameter and focal length of the XACT optic. (Right) Amptek SDD detectors with and without the TO-8 cap. The thin silicon-nitride entrance window is built into the cap. NICER XRCs and detectors are now flight qualified.

INSTRUMENTS: Wide Field Monitor (WFM)

- Coded Mask imager similar to that employed on several previous missions. Based on LOFT m-class design.
- Energy range: 2-50 keV
- Energy resolution: 300 eV FWHM @6 keV, using SDDs similar to LAD
- Effective area/ camera pair: 364 cm^2
- Sky coverage: 1/3 of the sky (instantaneous)
- Position accuracy: 1 arcmin
- Time resolution: 10 μs

References:

[1] Gendreau, K.C. et al. The Neutron star Interior Composition Explorer (NICER): design and development. *Proc. SPIE* 2016, vol 9905, p 99051H-9905H-16

[2] Feroci, M. et al. The Large Observatory for X-ray Timing (LOFT). Experimental Astronomy 2012; 34:415-444.

[3] Balsamo, E. et al Development of full shell foil x-ray mirrors. Proc. SPIE 8450, 845052-845052-19

Mission Study Parameters

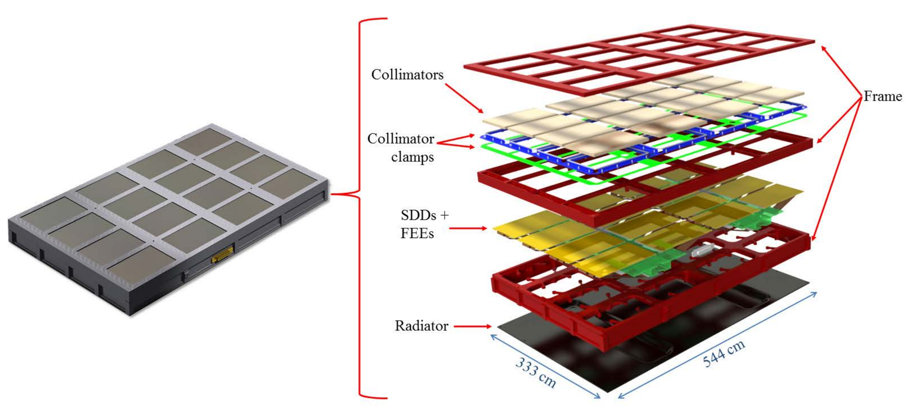
- Flexible 3-axis pointing over a large fraction of the sky with autonomous repoint capability
- Orbit: LEO, 500-600 km altitude, as low inclination as possible
- Launcher: Falcon 9 FT
- Cost: <$1B including launch
- STROBE-X is part of a NASA funded 18-month study of Probe-class Missions for the 2020 decadal survey. Mission and Instrument studies were performed at GSFC in 2017 and 2018

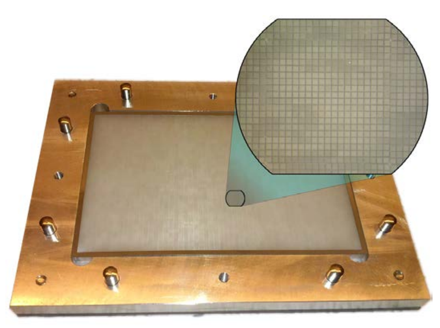
Key Science Goals

- Probe stationary spacetimes near black holes to explore the effects of strong field general relativity and measure the masses and spins of BHs
- Map the geometry of BH accretion flows, using X-ray reverberation, across all mass scales from stellar mass BHs in our galaxy to supermassive BH in AGN
- Fully determine the ultradense matter equation of state by measuring the neutron star mass-radius relation using >20 pulsars over an extended mass range.
- High duty cycle survey of the dynamic X-ray sky with high spectral and high time resolution, enabling multi-wavelength studies and follow-up to multi-messenger gravitational waves and neutrinos.

INSTRUMENTS: Large Area Detector (LAD)

- Lightweight MCP collimators enable an order of magnitude increase in area over RXTE. Developed for the European LOFT M-class mission
- Energy range: 2-30 keV
- Energy resolution: 300 eV FWHM (CCD quality)
- Effective area @10 keV ~5 m^2 (60 LAD modules, 8×RXTE)
- Time resolution: 10 μs





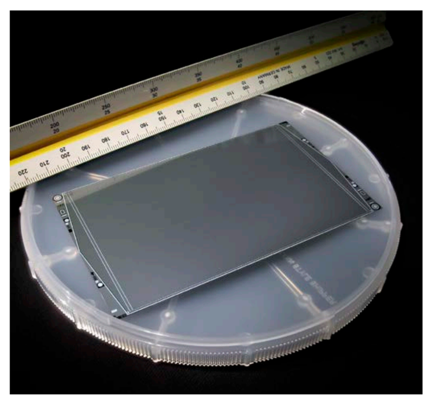
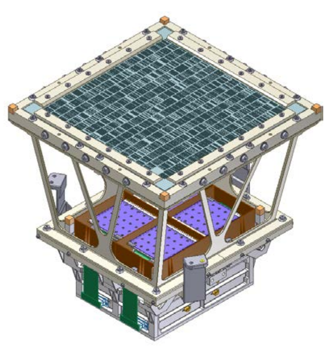
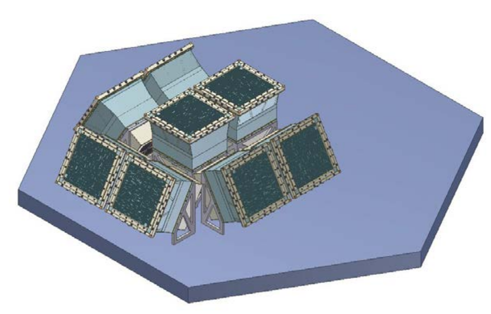


Figure 3: (Left) The assembled LAD module as well as the exploded view of its components, (Center) Lead-glass micro-capillary plate (MCP) collimator tile in its transport frame. (Right) A large area SDD developed for the European LOFT mission.





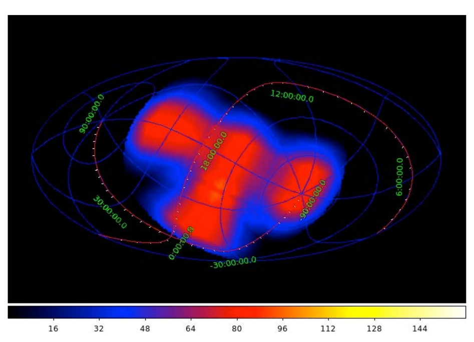


Figure 4: (Left) Detailed view of a single WFM camera. (Center) Configuration of the WFM on LOFT. (Right) Combined FOV of the WFM on the sky for LOFT, for a typical galactic center pointing.