New Horizons in Time-Domain Astronomy
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LOFT: Large Observatory For X-Ray Timing

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Abstract. High-time-resolution X-ray observations of compact objects provide direct access to strong-field gravity, black-hole masses and spins, and the equation of state of ultra-dense matter. LOFT†, the Large Observatory for Xray Timing, is specifically designed to study the very rapid X-ray flux and spectral variability that directly probe the motion of matter down to distances very close to black holes and neutron stars. A 10-m^2-class instrument in combination with good spectral resolution (<260 eV @ 6 keV) is required to exploit the relevant diagnostics, and has the potential of revolutionising the study of collapsed objects in our Galaxy and of the brightest supermassive black holes in active galactic nuclei. LOFT will carry two main instruments: a Large Area Detector (LAD), to be built at MSSL/UCL in collaboration with the Leicester Space Research Centre, and a Wide Field Monitor (WFM). The ground-breaking characteristic of the LAD (it will work in the energy range 2–30 keV) is a mass per unit surface in the range ∼10 kg/m^2, giving an effective area of ∼10 m^2 (@10 keV) at a reasonable weight—an improvement by ∼20 over all predecessors. This will allow timing measurements of unprecedented sensitivity, providing the capability to measure the mass and radius of neutron stars with ∼5% accuracy, or to reveal blobs orbiting close to the marginally stable orbit in active galactic nuclei. We summarise the characteristics of the LOFT instruments and give an overview of its expected capabilities.

Keywords. space vehicles: instruments; stars: neutron; pulsars: general; radiation mechanisms: general; equation of state; gravitation

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1. A New X-Ray Mission

LOFT is one of four M3 missions that have been selected by ESA for an Assessment Phase and to be considered for a possible launch in 2020–2022. The LOFT Consortium includes institutes across the UK, Europe, Israel, Turkey, Canada, the US and Brazil. In addition to MSSL, the UK participation includes the Space Research Centre (SRC) in Leicester and the Universities of Southampton, Durham, Manchester and Cambridge. The UK participation is sponsored by the UK Space Agency. MSSL/UCL will lead the LOFT Large Area Detector (LAD) instrument within the consortium (S. Zane and D. Walton), and will also have a major role in hardware/software development and system engineering (thermal, mechanical, electronics and software). Those efforts will be supported by Leicester SRC (G. Fraser) in leading the development of the collimators.

LOFT (Feroci *et al.* 2011a,b) is a 10-m^2-class telescope specifically designed to study the very rapid X-ray flux and spectral variability that directly probe the motion of matter down to distances very close to black holes and neutron stars. High-time-resolution X-ray observations of compact objects provide direct access to strong-field gravity, black-hole masses and spins, and the equation of state of ultra-dense matter. They provide

† http://www.isdc.unige.ch/loft/index.php/the-loft-mission

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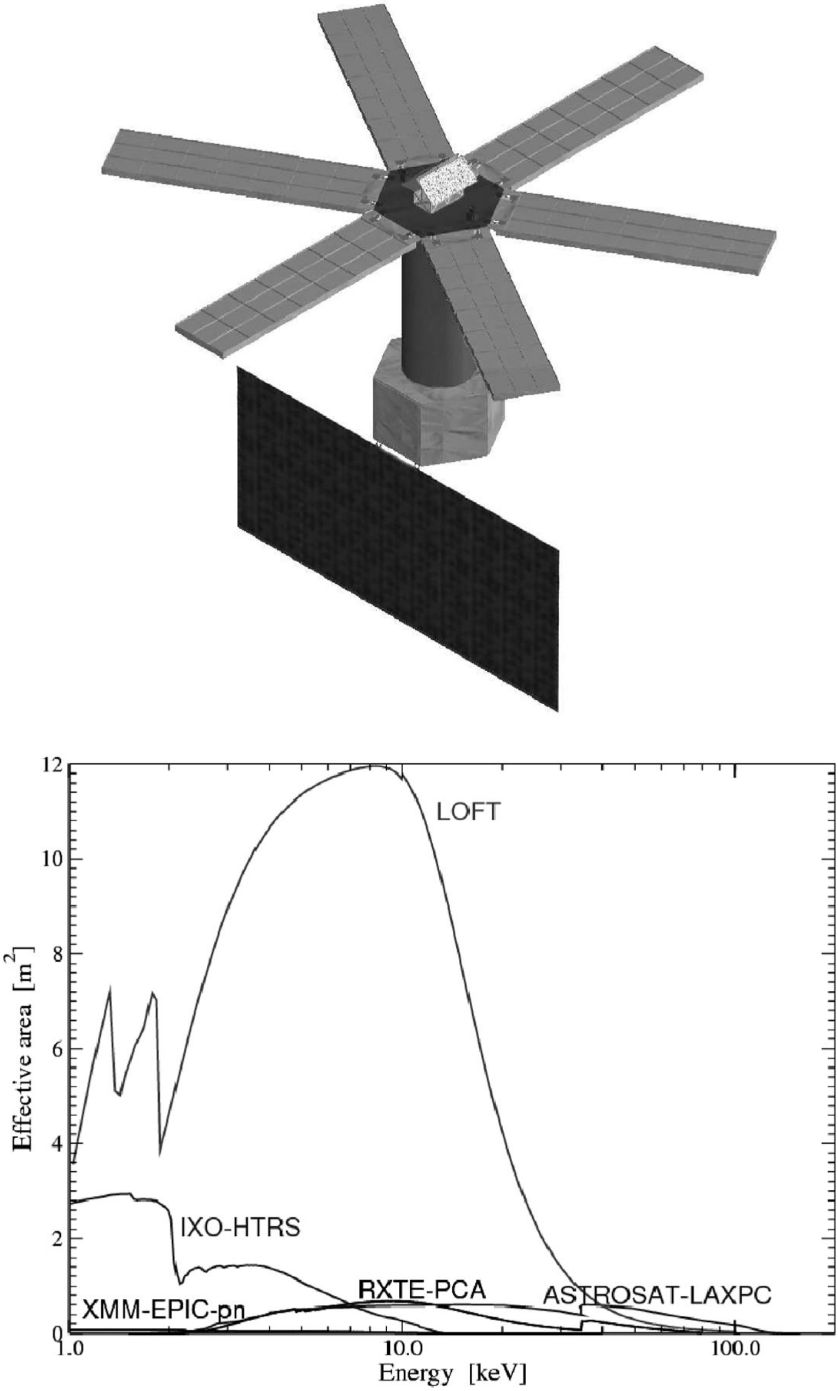

Figure 1. Upper: Conceptual scheme of the *LOFT* satellite. From top to bottom along the satellite axis: Wide Field Monitor, optical bench, the six Large Area Detector petals, structural tower, bus, and solar array. Lower: LAD effective area plotted against energy in linear scale, as compared to that of other satellites for X-ray astronomy (from Feroci *et al.* 2011a)

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unique opportunities to reveal for the first time a variety of general relativistic effects, and to measure fundamental parameters of collapsed objects. They offer unprecedented information on strongly curved space-times and matter at supra-nuclear densities and in supercritical magnetic fields. That in turn bears directly on several fundamental questions raised both by ESA's Cosmic Vision Theme, "Matter under extreme conditions", and the STFC road map, "What are the laws of physics under extreme conditions?"

A 10-m^2-class telescope like LOFT requires the combination of good spectral resolution (<260 eV @ 6 keV) in order to exploit the relevant diagnostics. It will then have the potential to revolutionise the study of collapsed objects in our Galaxy and of the brightest supermassive black holes in active galactic nuclei (AGNs). The time-scales and phenomena that LOFT will investigate range from sub-millisecond, quasi-periodic oscillations to year-long transient outbursts, and the objects to be studied include many that flare up and change state unpredictably. Relatively long observations, flexible scheduling and continuous monitoring of the X-ray sky are therefore essential elements for success in this project.

2. Payload

LOFT will be launched in a ∼600 km equatorial orbit. It will carry two instruments: a Large Area Detector (LAD), operating in the 2–50 keV range with energy resolution <260 eV (@ 6 keV), and a Wide Field Monitor (WFM). The LAD consists of 6 panels deployable in space (Fig. 1, upper) which provide a total effective area of ∼10 m^2 (@ 10 keV), improving by a factor of ∼20 over its predecessors (Fig. 1, lower). The groundbreaking characteristic of the LAD is a mass per unit area of ∼10 kg/m^2, a factor of 10 lower than the *RXTE*/PCA, enabling a ∼10-m^2-area payload at reasonable weight. The ingredients for a sensitive but light experiment are the large-area Silicon Drift Detectors, and a collimator based on lead-glass micro-channel plates. An unprecedently large throughput (∼3×10^5 cts/s from the Crab) will be achieved, while making pile-up and dead-time secondary issues. The WFM is a coded-mask telescope mounted at the top of the structural tower at the centre of the LAD deployable array. The WFM will operate in the energy range 2–50 keV and with a field of view of 3 steradians, corresponding to ∼1/4 of the whole sky. The WFM angular resolution (5 arcmin) will enable it to locate sources with a 1-arcmin accuracy, with a 5σ sensitivity of 2 mCrab (50 ks). Some characteristics of the instrumentation are given in Table 1.

3. The LOFT Science Driver: Study of Matter under Extreme Conditions

The science drivers for LOFT are the study of the neutron-star structure and the equation of state (EOS) of ultra-dense matter (mass, radius and crustal properties of neutron stars), the motion of matter under strong gravity conditions and the mass and spin of the black holes via the study of quasi-periodic oscillations (QPOs) in the time domain, relativistic precession, Fe-line reverberation studies in AGNs, the measure of small-amplitude periodicities in X-ray transients, millisecond pulsars, etc., discovery of new X-ray transients, early trigger of jets over many astronomical scales, X-ray flashes, and many others.

The LAD ∼10-m^2 effective area in the 2–50 keV energy range will allow timing measurements of unprecedented sensitivity, leading for instance to measuring the mass and radius of neutron stars with ∼5% accuracy, or to reveal blobs orbiting close to the

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Table 1. Overview of the LOFT instrument performances.

Item	**Requirement**	**Goal**
Large Area Detector (LAD)		
Energy Range	2–50 keV	1–50 keV
Effective Area (2–10 keV)	10 m^2 @ 8 keV	12 m^2 @ 8 keV
Energy Resolution (@ 6 keV)	260 ev @ 6 keV	200 ev @ 6 keV
Field of View (FWHM)	$< 1°$; transparency $<1\%$ @ 20 keV	30 arcmin
Time Resolution	$10\mu s$	$7\mu s$
Dead Time	$<1\%$ (@1 Crab[1])	$<0.5\%$ (@1 Crab)
Background	$<$ 10 mCrab	$<$ 5 mCrab
Maximum source flux (steady,peak)	$>$500mCrab; $>$15 Crab	$>$500mCrab; $>$30 Crab
Wide Field Monitor (WFM)		
Energy Range 2–50 keV	1–50 keV	
Energy Resolution (FWHM)	500 eV	300 eV
Field of View	50% of the accessible LAD sky coverage	Same, with improved sensitivity
Angular Resolution	5 arcmin	3 arcmin
Point Source Localisation	1 arcmin	0.5 arcmin
Sensitivity (5σ, 50 ks)	5 mCrab	2mCrab

Notes: [1] Flux values are in units of the Crab pulsar flux in the energy range of interest.

marginally stable orbit in active galactic nuclei. The LAD energy resolution will also allow the simultaneous exploitation of spectral diagnostics, in particular from the relativistically broadened 6–7 keV Fe-K lines. The WFM will monitor a large fraction of the sky and constitute an important resource in its own right. The WFM will discover and localise X-ray transients and impulsive events and monitor spectral state changes with unprecedented sensitivity. It will then trigger follow-up pointed observations with the LAD as well as with other multi-wavelength facilities.

References

Feroci, M., *et al.* 2011a, *Experimental Astronomy*, in press

Feroci, M., *et al.* 2011b, *Proceedings of the SPIE*, 7732, 57

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