LOFT: Large Observatory For X-ray Timing

S. Zane, R. P. Mignani, D. Walton, T. Kennedy. B. Winter, P. Smith (MSSL, UCL, UK)
on behalf of the LOFT team

Loft Consortium and UK partnership

The LOFT Consortium includes several institutes across the UK, Europe, Israel, Turkey, Canada, the US, and Brazil. In addition to MSSL, the UK participation include the Space Research Centre (SRC) in Leicester, the University of Southampton, the University of Durham, the University of Manchester, and the University of Cambridge. The UK participation is sponsored by the UK Space Agency.

A New X-ray Mission

LOFT is one of four M3 missions that have been selected by ESA for an Assessment Phase and be considered for a possible launch in 2020-2022. LOFT is a 10 m²-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 unique opportunities to reveal for the first time a variety of general relativistic effects, and to measure fundamental parameters of collapsed objects. They gain unprecedented information on strongly curved space times and matter at supra-nuclear densities and in supercritical magnetic fields. In turn, this bears directly to answer several fundamental questions of both the ESA's Cosmic Vision Theme *"Matter under extreme conditions"* and the STFC road map *"What are the law of the physics under extreme conditions?"*.

A 10 m²-class telescope as LOFT, in combination with good spectral resolution (<260 eV @6 keV) is required to exploit the relevant diagnostics and holds the potential to revolutionise the study of collapsed objects in our galaxy and of the brightest supermassive black holes in active galactic nuclei. The timescales/phenomena that LOFT will investigate range from sub-millisecond, quasi-periodic oscillations to year-long transient outbursts, and the relevant objects include many that flare up and change state unpredictably. Thus, relatively long observations, flexible scheduling and continuous monitoring of the X-ray sky are essential elements for success.

Payload

LOFT will be launched on a Soyuz rocket at a ~600 km equatorial orbit. It will carry two main instruments: a Large Area Detector (LAD, operating in the range 2-50keV, energy resolution <260eV @6keV) and a Wide Field Monitor (WFM). The LAD consists of 6 panels deployable in space which provide a total effective area of ~10 m² (@8 keV), improving by a factor of ~20 over all its predecessors (Fig.1). The ground-breaking characteristic of the LAD is a mass per unit surface of ~10 kg/m², a factor of 10 lower than for the RXTE/PCA, enabling a ~10 m² 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 microchannel plates. An unprecedently large throughput (~3x10⁵ 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 ot the top of the telescope axis 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 about ¼ of the whole sky. The WFM angular resolution (5 arcmin) will enable it to locate sources with an accuracy of 1 arcmin, with a 5σ sensitivity of 2mCrab (50 ks).

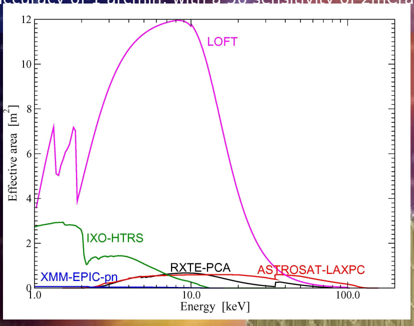

Fig. 1: Effective area of LOFT compared to that of other missions

Parameter	Requirement	Goal
	Large Area Detector	
Energy Range	2-50 keV	1.5-50 keV
Effective Area (2-10 keV)	10m²@8keV	12 m²@8keV
Energy Resolution (@ 6 keV)	260 eV @6keV	200 eV @6keV
Field of View (FWHM)	<1° and transparency ~1% at 30 keV	<0.5°
Time Resolution	10 μs	7 μs
Dead Time	<1% (@ 1 Crab)	<0.5% (@ 1 Crab)
Background	< 10 mCrab	< 5 mCrab
Maimum source flux (continuous and re-binned in energy >30keV,continuos re-binned)	>500 mCrab, 15 Crab	>750mCrab, 30 Crab
	Wide Field Monitor	
Energy Range	2-50 keV	1-50 keV
Energy Resolution (FWHM)	500 eV	300 eV
Field of View	50% of the sky accessible to the LAD	Same, with improved sensitivity
Angular Resolution	5 arcmin	3 arcmin
Point Source Localization	1 arcmin	0.5 arcmin
Sensitivity (5σ, 50 ks)	5 mCrab	2 mCrab

EXPLORING THE 4TH DIMENSION

The LOFT Science Driver: study of matter under extreme conditions

- Neutron Star Structure and Equation of State of ultradense matter (mass, radius and crustal properties of neutron stars)
- Strong Gravity and the mass and spin of the black holes (QPOs in the time domain, relativistic precession, Fe line riverberation studies in AGNs..)
- 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 m² effective area in the 2-50 keV energy range will allow timing measurements of unprecedented sensitivity, leading for instance the 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.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 obs as with other multi-wavelength facilities.

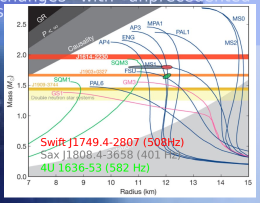

Fig 2. Mass-radius curves for different neutron star EOS: nucleonic (blue), nucleonic plus exotic (pink) and strange quark (green) matter. Green ellipse: the 90% confidence level limits on M, R from a simulated pulse profile rising phase of a type I X-ray burst (Stromayer, 2004). Uncertainty is <5% on both M and R. Gray and red ellipses show similar constraints from simulated pulse profiles of two accreting millisecond pulsars.

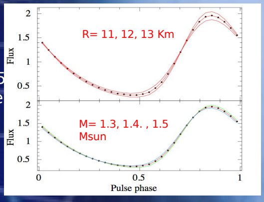

Fig. 3 Simulated pulse profile measurements from burst oscillations during the rising phase of an X-ray burst or from an accreting millisecond pulsar. The spin frequency is 400 Hz, as in SAX J1808.4-365. The dots mark the input profile, with errors as large as the dot size. These panels demonstrate the very high sensitivity to mass and radius measurements that can be reached with LOFT.

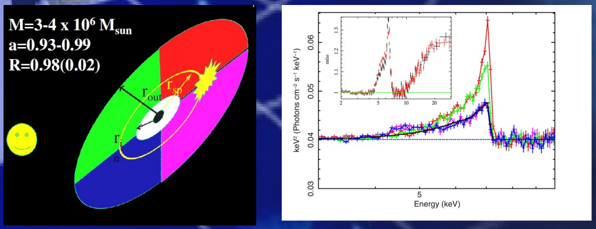

Fig. 4: Iron reverberation studies in bright AGNs. The figure is illustrative of the case of MCG-6-30-15, different coloured lines correspond to 4 different orbital phases for a line emitted at 10rg. LOFT can map the 4 phases in four cycles, with 1000s each, allowing to measure the black hole mass and spin (M=3-4 x10⁶ Msun, a=0.93-0.99).

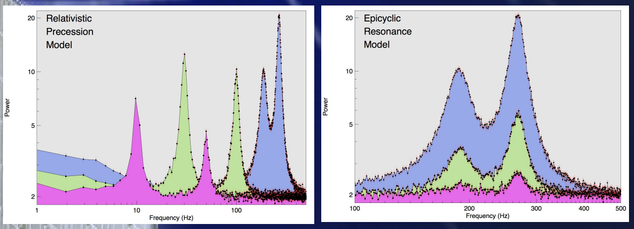

Fig. 5: LOFT study of the QPO evolution with flux (blue 1 Crab, green 400mCrab, violet 300mCrab) in two different scenarios → LOFT will solve the ambiguity in the interpretation of the QPO phenomena, providing access to genuine general relativistic effects (e.g. Lense-Thirring or strong field periastron precession) and to the mass and spin of the black hole.

Jan Willem Den Herder, Marco Feroci, Enrico Bozzo, Luigi Stella, Michiel van der Klis on behalf of the LOFT team
Silvia Zane, Dave Walton, Roberto Mignani, Tom Kennedy on behalf of the LAD team

Note: MSSL/UCL will lead the LOFT LAD instrument within the consortium (Silvia Zane, Dave Walton, Tom Kennedy) as well as will have a major role in the hardware/software development and system engineering (thermal, mechanical, electronics and software). This effort will be supported by Leicester SRC (G. Fraser) who lead the development of the collimators. Southampton, Durham. Manchester, and Cambridge are among the other UK institutions currently involved in the LOFT Science consortium.

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