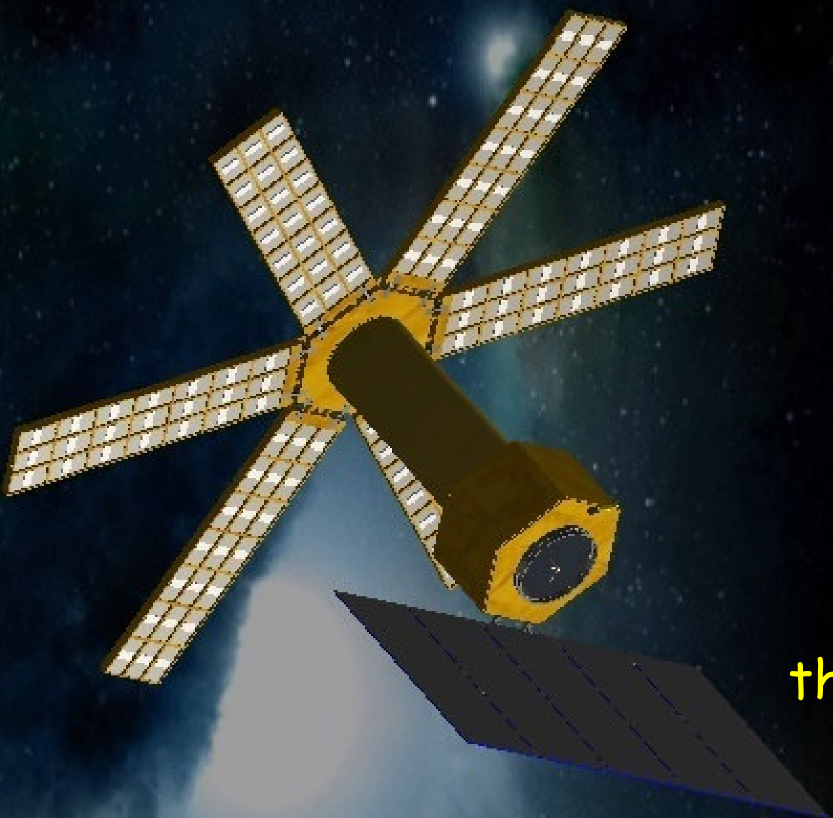
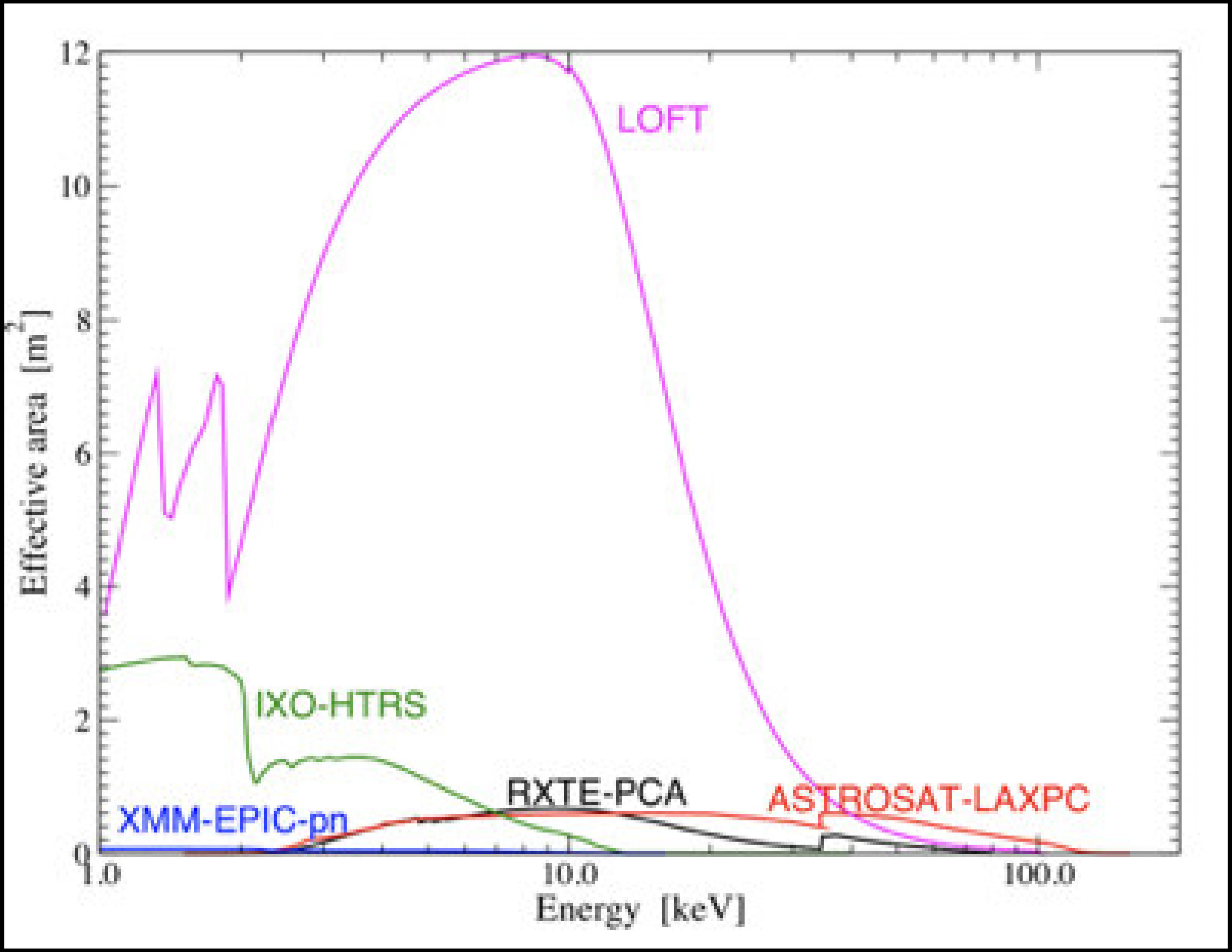
LOFT
Large Observatory For x-ray Timing



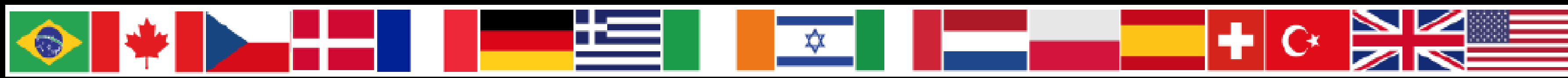
A mission proposal selected by ESA
as a candidate CV M3 mission
devoted to X-ray timing
and designed to investigate
the space-time around collapsed objects

Marco Feroci (INAF, IASF Rome)
on behalf of the LOFT Consortium

LOFT in one plot



Who is LOFT



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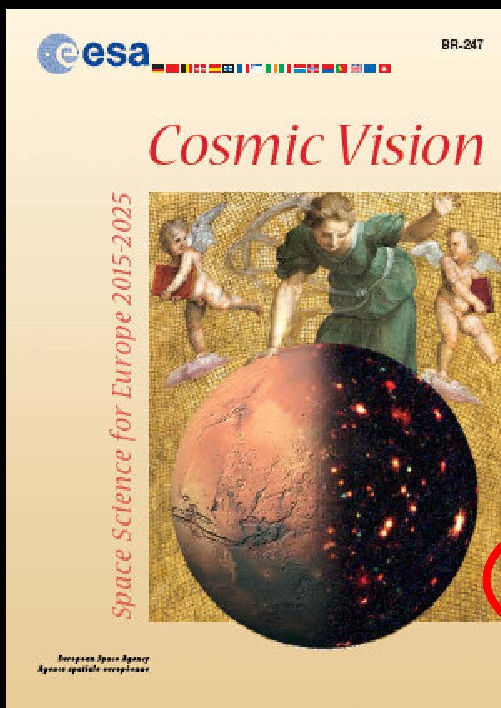
Paul Ray	Naval Research Lab, USA
Joao Braga	INPE, Brazil

on behalf of more than 250 scientists from:
Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, the Netherlands, Poland, Spain, Switzerland, Turkey, United Kingdom, USA

LOFT will fully address Fundamental Question 3.3 "Matter under extreme conditions" put forward by the ESA's Cosmic Vision



3. What are the fundamental physical laws of the Universe?

3.1 Explore the limits of contemporary physics

Use stable and weightless environment of space to search for tiny deviations from the standard model of fundamental interactions

3.2 The gravitational wave Universe

Make a key step toward detecting the gravitational radiation background generated at the Big Bang

3.3 Matter under extreme conditions

Probe gravity theory in the very strong field environment of black holes and other compact objects, and the state of matter at supra-nuclear energies in neutron stars

The LOFT Mission

LOFT is specifically designed to exploit the diagnostics of 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, as well as the physical state of ultradense matter.

LOFT will investigate variability from submillisecond QPO's to years long transient outbursts.

The LOFT LAD has an effective area ~20 times larger than its largest predecessor (the Proportional Counter Array onboard RossiXTE) and a much improved energy resolution.

The LOFT WFM will discover and localise X-ray transients and impulsive events and monitor spectral state changes, triggering follow-up observations and providing important science in its own.

Marco Feroci (IASF Rome)

The LOFT Science Drivers

Neutron Star Structure and Equation of State of ultradense matter:

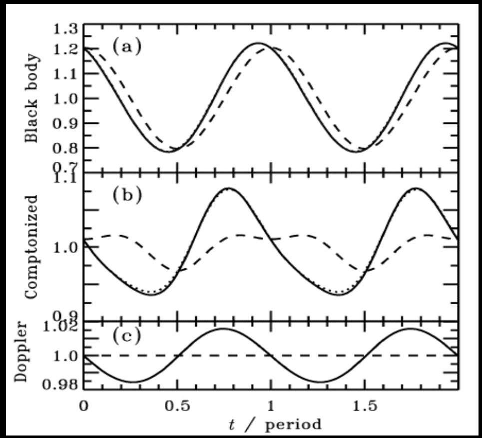
- neutron star mass and radius measurements
- neutron star crust properties

Strong gravity and the mass and spin of black holes

- QPOs in the time domain
- Relativistic precession
- Fe line reverberation studies in bright AGNs

Pulse Shape Modelling and Fitting in Neutron Stars

X-ray oscillations are produced by hot spots rotating at the neutron star surface.
Modeling of the pulses (shape, energy dependence) taking into account Doppler boosting, time dilation, gravitational light bending and frame dragging will constrain the M/R of the NS.

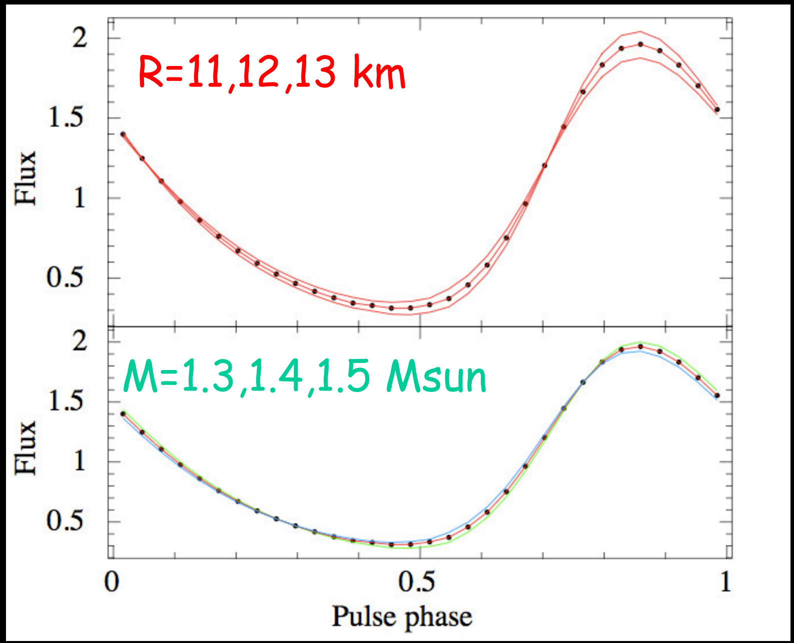


Poutanen and Gierlinski 2003

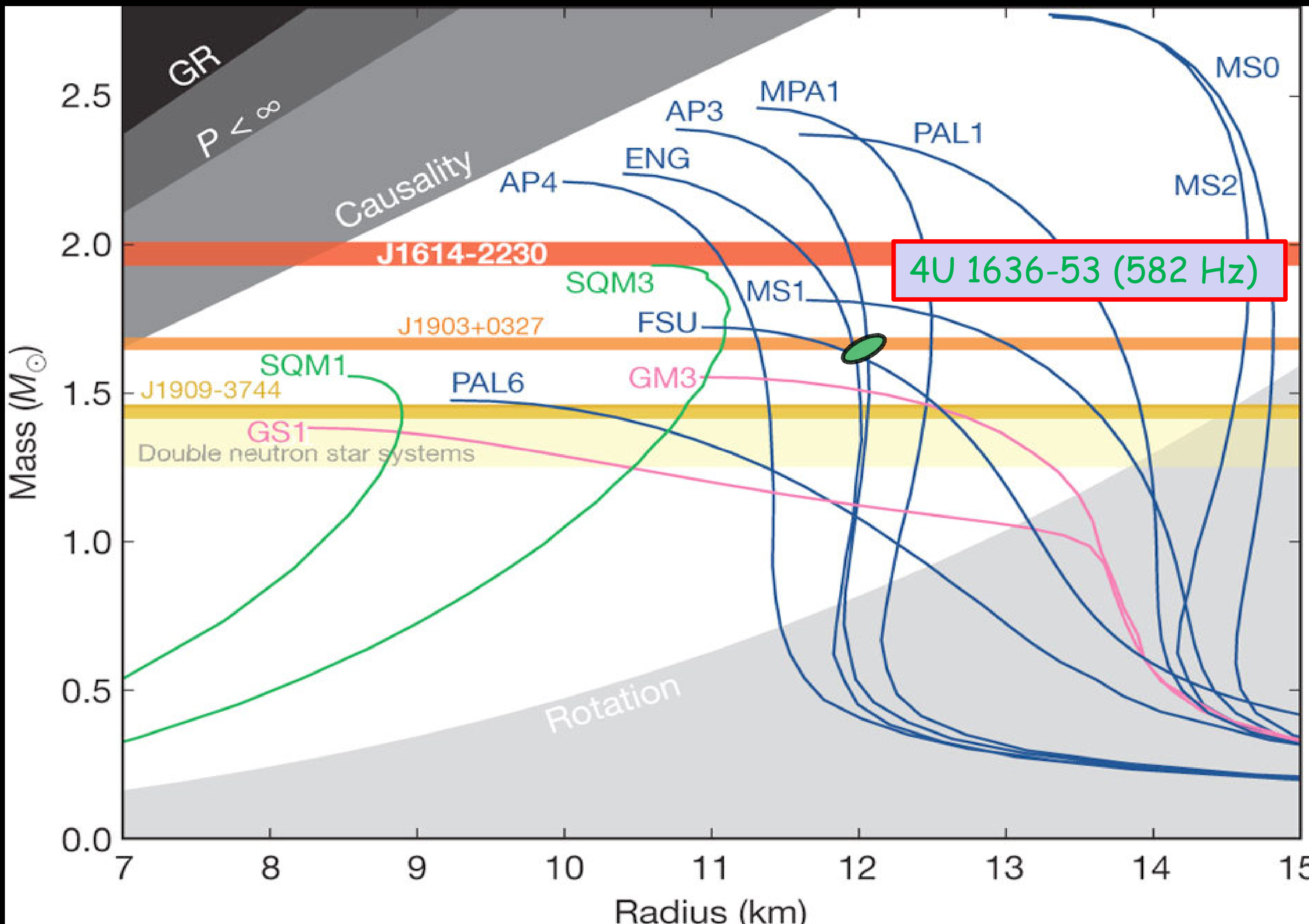
LOFT simulation: SAX J1808.4-3658

Simulation of the (401 Hz) pulse profile measurement

On coherent pulsations and/or burst oscillations:
5% uncertainty (90% confidence level) on mass and radius



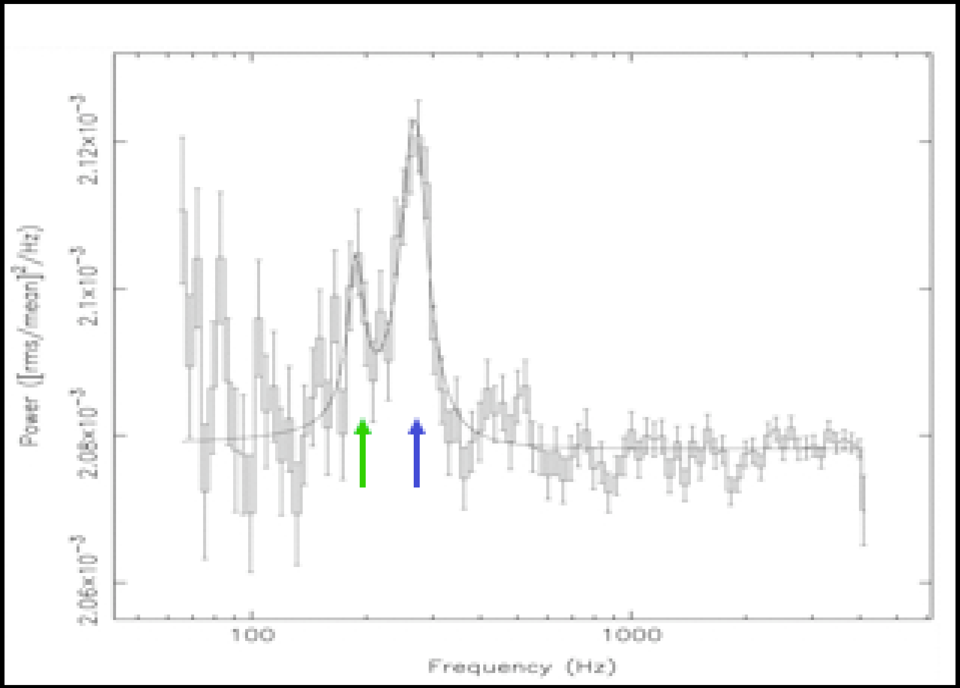
LOFT Constraints to NS EOS from M-R measurements



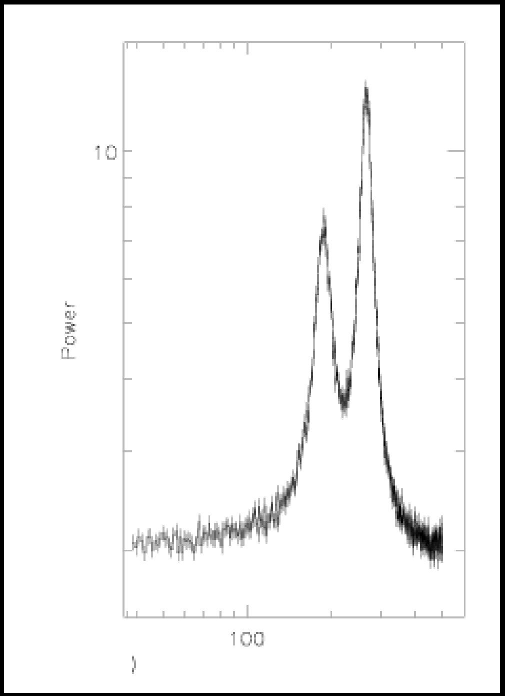
from Demorest et al. 2010

The high frequency QPOs in the BHC XTE J1550-564

ν₁=188 Hz, ν₂=268 Hz, frac rms ν₁= 2.8%, frac rms ν₂=6.2% (Miller et al. 2001), flux = 1 Crab, RXTE Exposure 54 ks, significance ~3-4σ.



LOFT simulation: Texp=1 ks

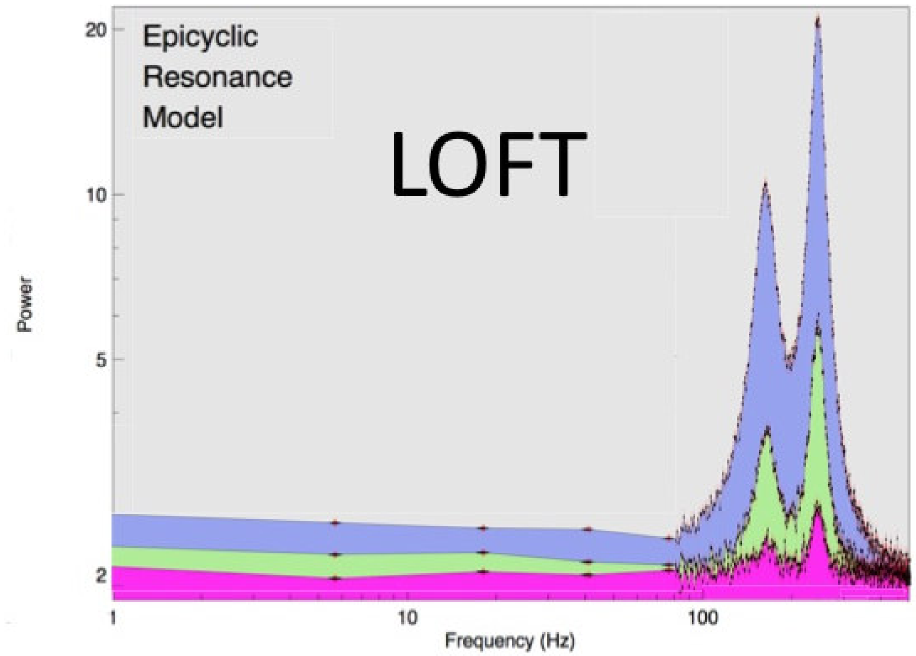


LOFT study of the QPO evolution with flux and fractional rms

Epicyclic Resonance Model

(Abramowicz & Kluzniak 2001)

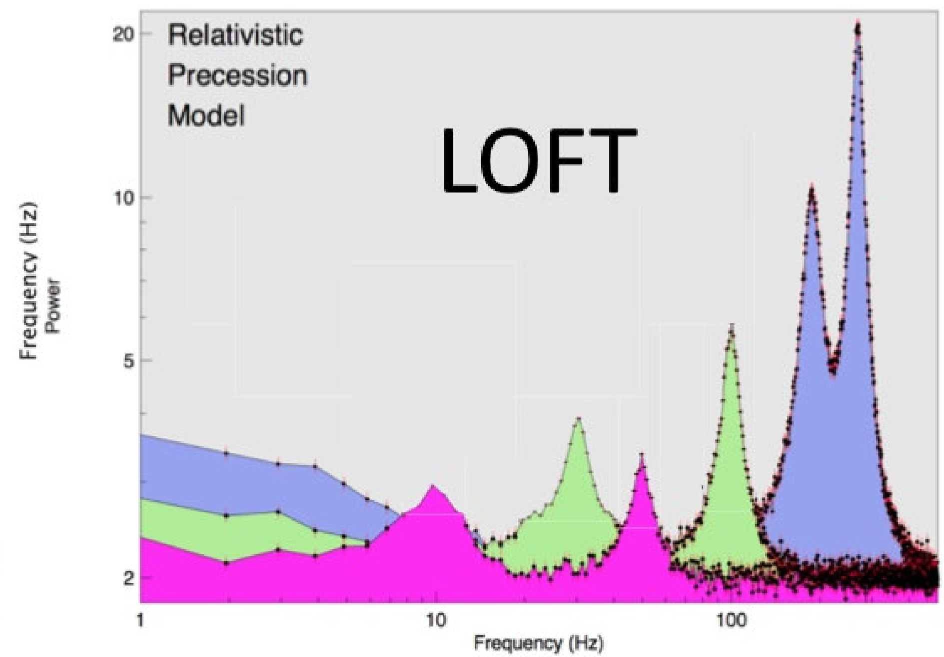
Predicts fixed frequencies



Relativistic Precession Model

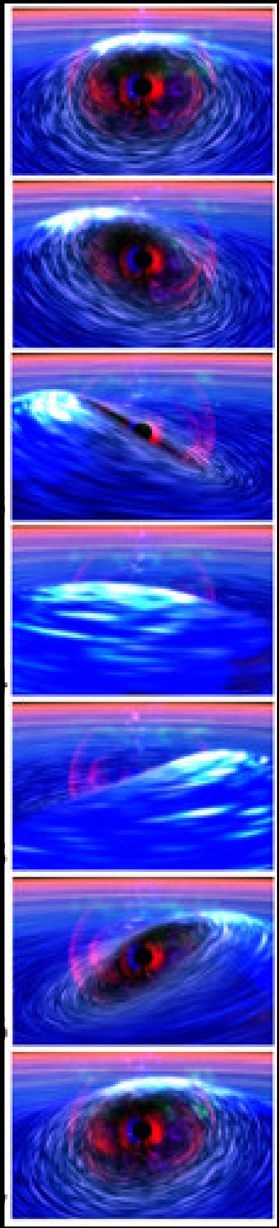
(Stella et al 1999)

Predicts variable frequencies

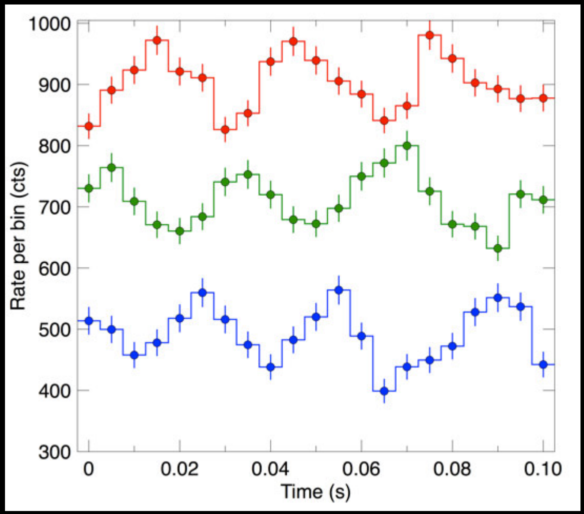


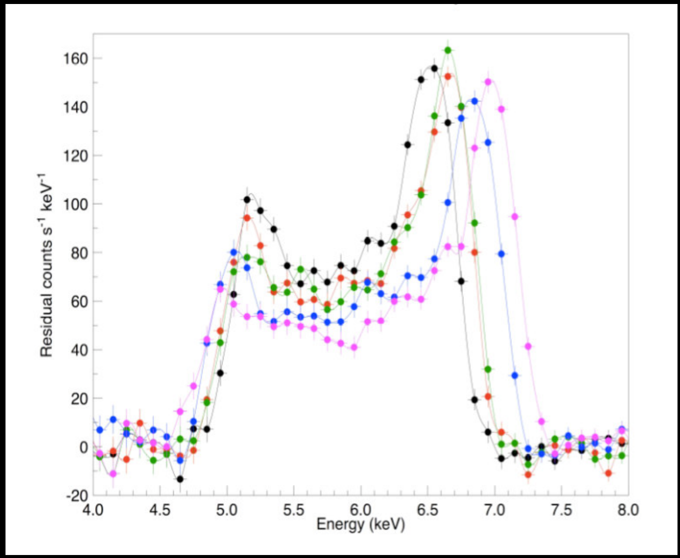
Once the ambiguity of the interpretation of the QPO phenomena is resolved, the frequency of the QPOs will provide access to general relativistic effects (e.g, Lense-Thirring or strong-field periastron precession) and to the mass and spin of the black hole.

QPOs in the time domain: inner disk nodal precession and Fe-Ka line

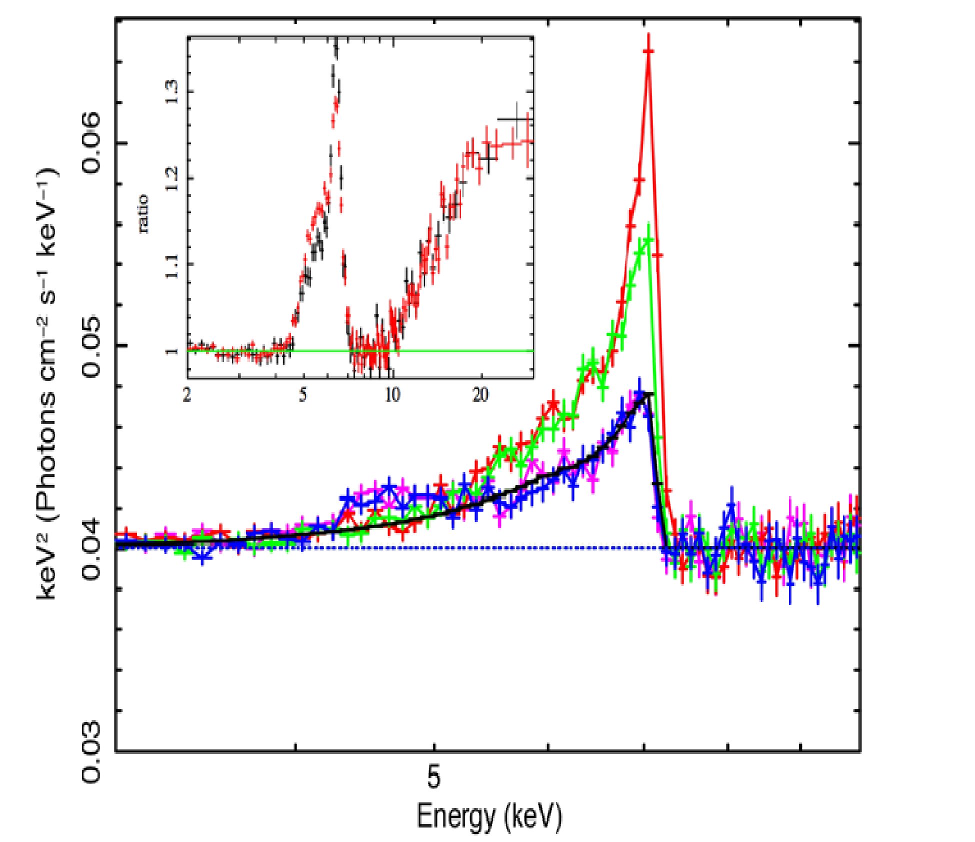


- Simulation of phase resolved spectroscopy of 30 Hz quasi periodic oscillations arising from Lense-Thirring precession of the inner disk (9-10 r_g) from a 300 mCrab neutron star binary (i=26°, 5° precession angle)
- Line emission from 9 to 100 r_g 10 ks exposure
- Continuum + steady line model gives unacceptable fit
- Addition of a line component from the precessing ring is required: varying ring inclination measured with 20% accuracy.





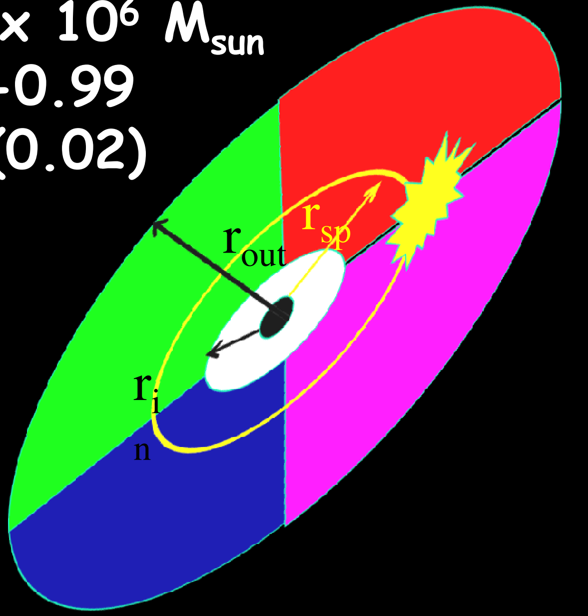
Fe line reverberation studies in bright AGNs



LOFT simulation of a steady and variable Fe line.

F=3mCrab, a=0.99, r_{in}=1r_g, r_{out}=100r_g, q=45°, $e \sim r^{-3}$, r_{sp}=10r_g, T_{orb}=4 ks
T_{exp}=16 ks → mapping 4 phases (1000 s each) in four cycles

M=3-4 × 10^6 M_{sun}
a=0.93-0.99
R=0.98(0.02)



AGNs for Fe line reverberation study with LOFT

Source	F(2-10 keV) cgs
IC4329A	9.5e-11
MCG-5-23-16	8.1e-11
ESO511-G030	1.3e-11
MCG-6-30-15	4e-11
NGC4051	2e-11
NGC3516	2e-11
NGC3783	6e-11
NGC3227	3e-11
MRK509	3.8e-11
MRK766	2.3e-11
ARK120	3.8e-11

- The fraction of relativistic Fe lines detected a flux limited XMM sample (FERO, de la Calle Pérez, 2010) is 36% (11/31).
- FERO is made of spectra of disparate quality and by the unavailability of a well-defined complete AGN sample --> the observed detection fraction can be considered as a lower limit
- ALL AGN with relativistic Fe profile will be observable with LOFT with Ns>500 up to 1300 (10^4s exposure) for brightest sources.

The LOFT Observatory

As for RXTE/PCA (but at much higher sensitivity), with a high flexibility in its observing program, LOFT will also be an Observatory for virtually all classes of relatively bright sources.

These include:

- X-ray bursters,
- High mass X-ray binaries
- X-ray transients (all classes)
- Cataclismic Variables
- Magnetars
- Gamma ray bursts (serendipitous)
- Nearby galaxies (SMC, LMC, M31, …)
- Bright AGNs
- …

The LOFT Mission

The LOFT Scientific Requirements (from proposal)

Parameter	Requirement	Goal
LAD		
Energy range	2–30 keV (nominal) 2-50 keV (expanded)	1–40 keV (nominal) 1–60 keV (expanded)
Effective area	12 m^2 (2-10 keV) 1.3 m^2 (@30 keV)	15 m^2 (2-10 keV) 2.5 m^2 (@30 keV)
Energy resolution (FWHM, @ 6 keV)	<260 eV (all events) <200 eV (40% of events)	<180 eV (all events) <150 eV (40% of events)
Field of view (FWHM)	<60 arcmin	<30 arcmin
Time resolution	10 μs	5 μs
Dead time	<0.5% (@ 1 Crab)	<0.1% (@ 1 Crab)
Background	< 10 mCrab	< 5 mCrab
Maximum source flux (steady, peak)	>300 mCrab, >15 Crab	>10 Crab, > 30 Crab
WFM		
Energy range	2-50 keV	1-50 keV
Energy resolution (FWHM)	<300 eV	<200 eV
Field of view	>3 steradian	>4 steradian
Angular resolution	5 arcmin	3 arcmin
Point source localization	1 arcmin	0.5 arcmin
Sensitivity (5 σ, 50 ks)	2 mCrab	1 mCrab
Sensitivity (5 σ, 1 s)	0.5 Crab	0.2 Crab

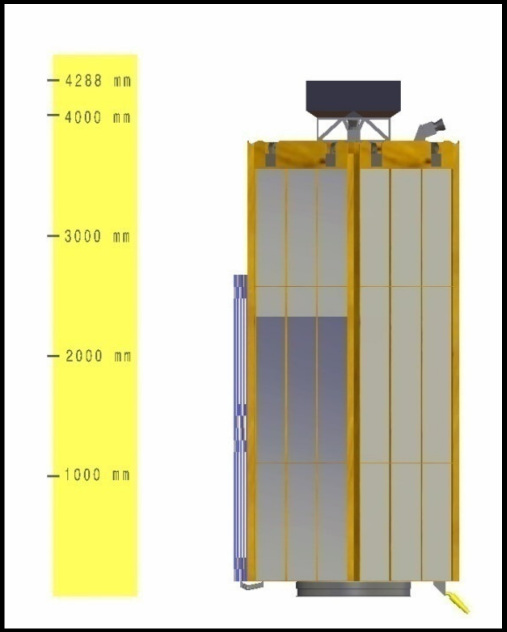
Marco Feroci (IASF Rome)

The LOFT Mission Profile

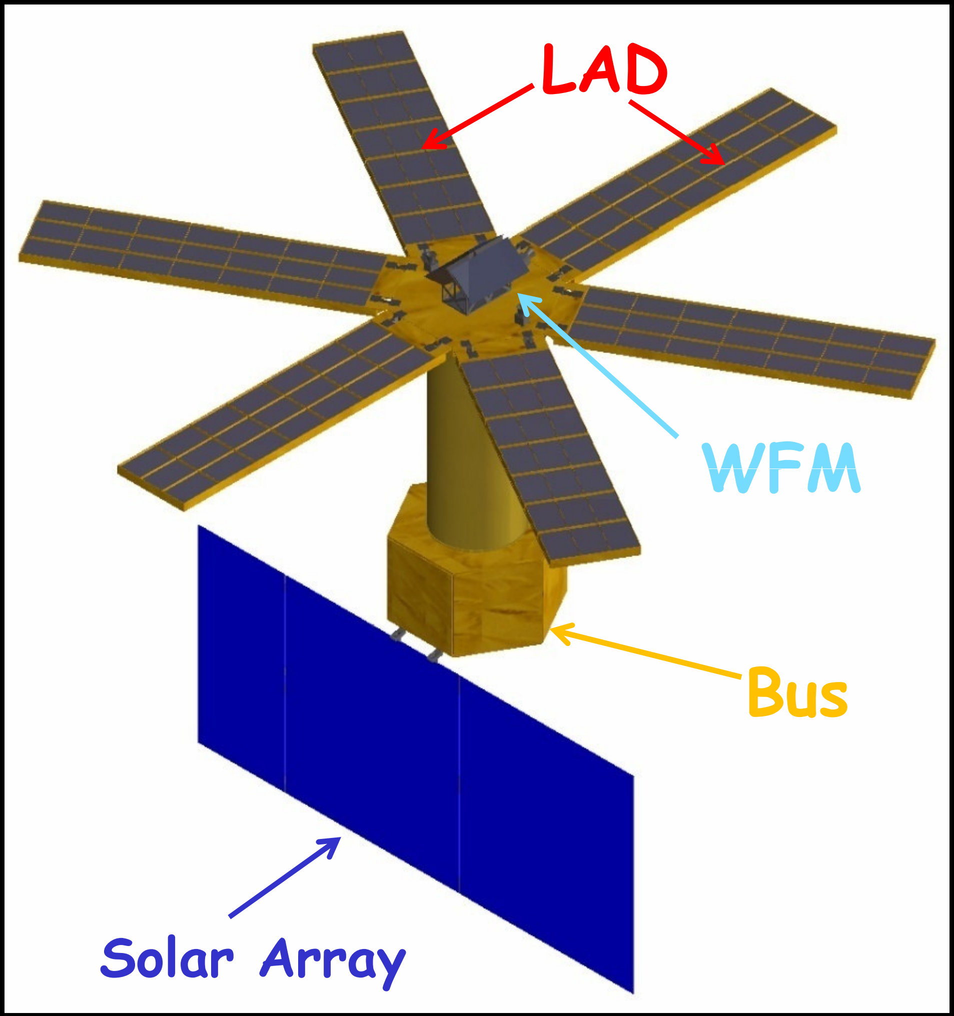
Orbit	Low earth (≤600 km), equatorial (<5°), circular
Launcher	Vega from Kourou
Satellite Mass	1800 kg (with margins)
Satellite Power	1800 W (with margins)
Slew rate	4° /minute
Telemetry	650 kbps
Ground Stations	Kourou, Malindi
Nominal Lifetime	2+2 years

The LOFT satellite

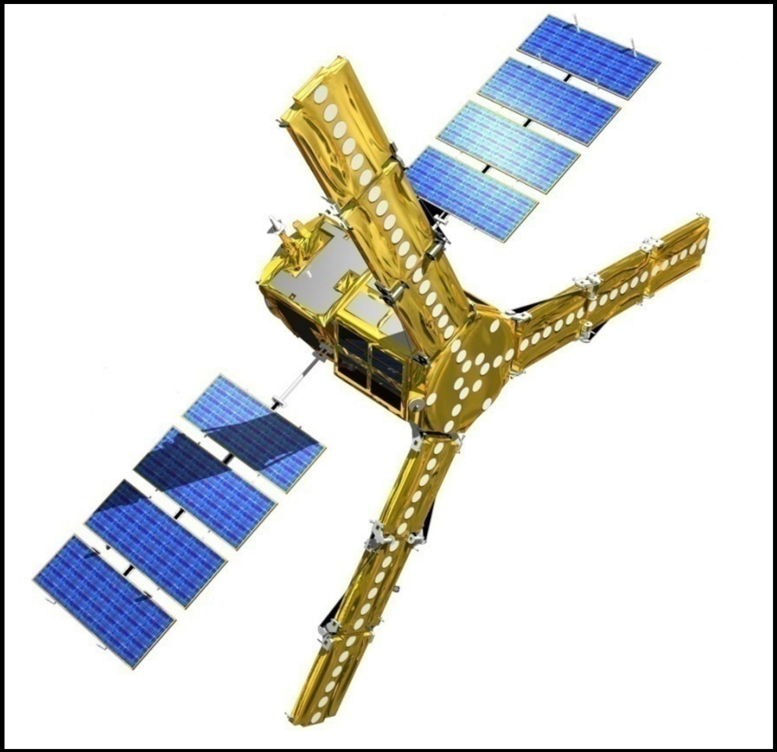
Industrial study by Thales Alenia Space - Italia

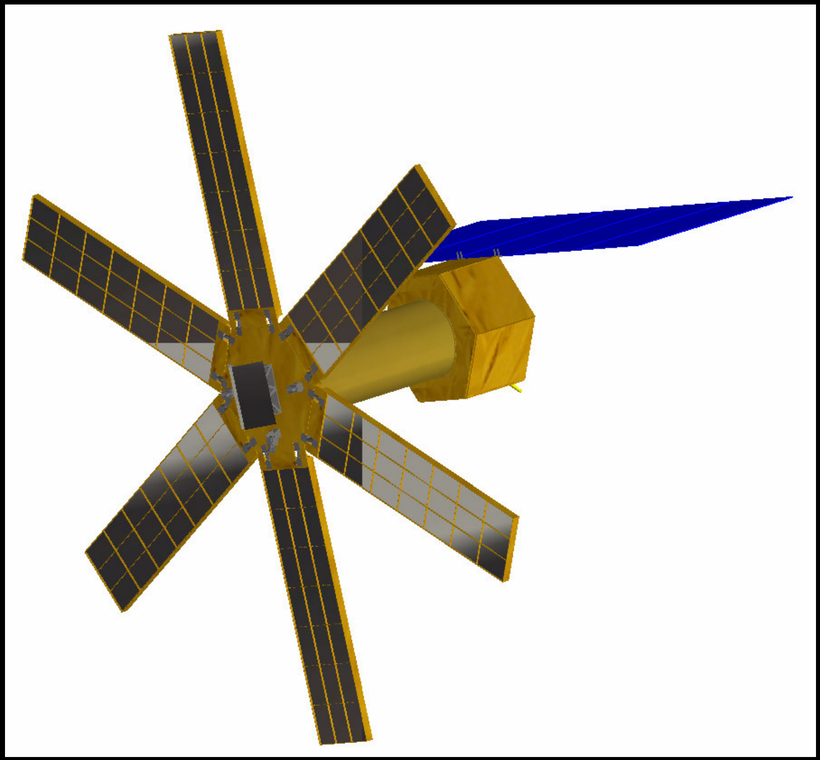


folded



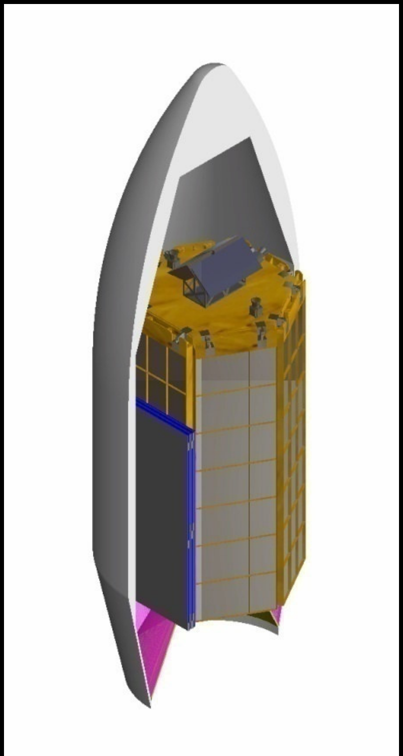
The SAR (Synthetic Aperture Radar) Missions Heritage





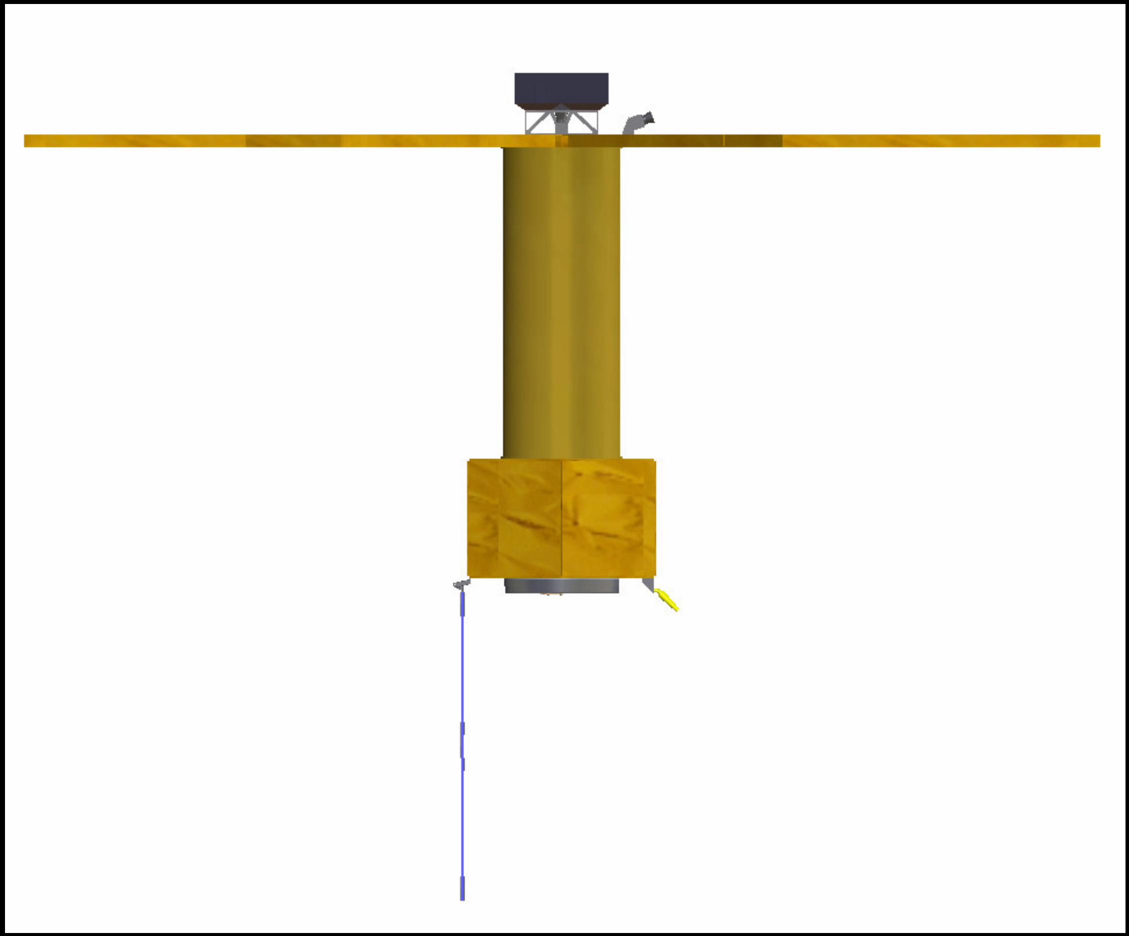
ESA-proven deployment technology
with sub-arcmin alignement accuracy

The LOFT satellite



stowed in the fairing of a Vega rocket

deployed



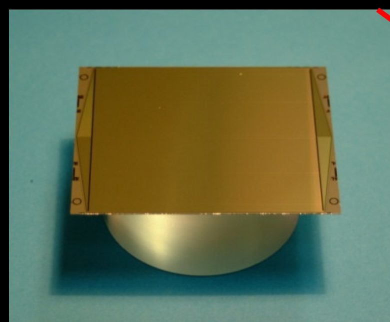
The LOFT enabling technologies

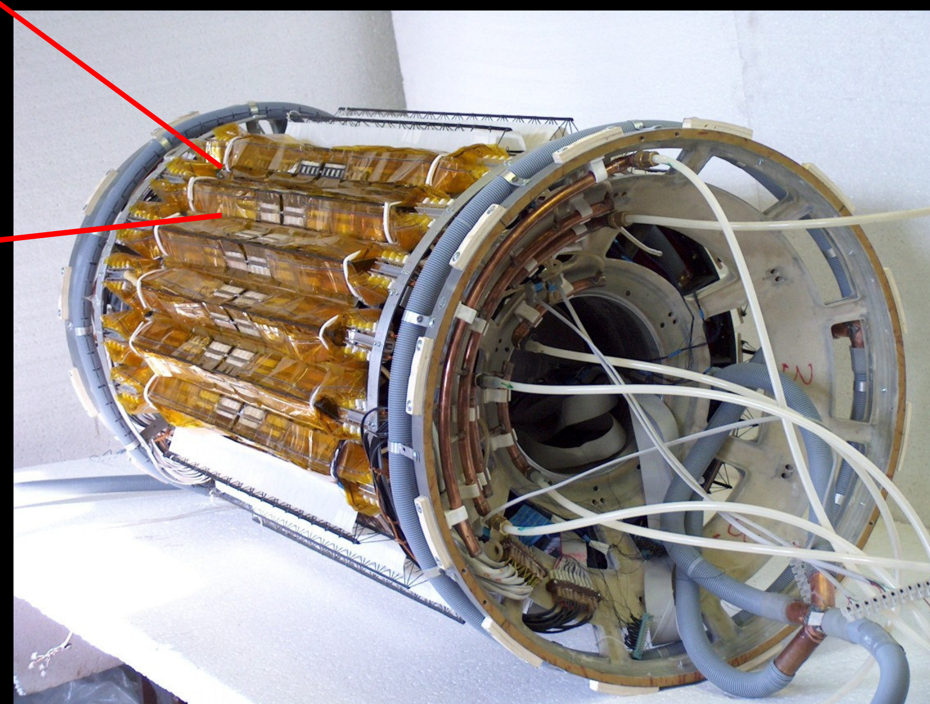
1. Large Area Silicon Drift Detectors
2. Capillary plates X-ray collimators

The Detector

An heritage of the Inner Tracking System of the ALICE experiment at the Large Hadron Collider (CERN)

INFN Trieste, in collaboration with Canberra Inc., designed, built, tested and calibrated 1.5 m^2 of SDD detectors (approximately 300 units), now operating since ~2 years. High TRL. Proven mass production.

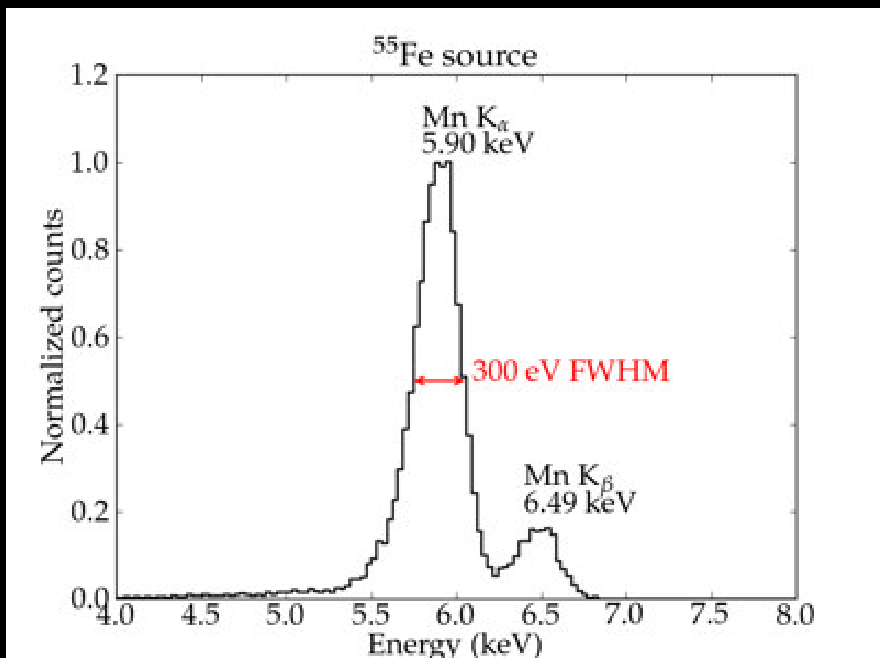


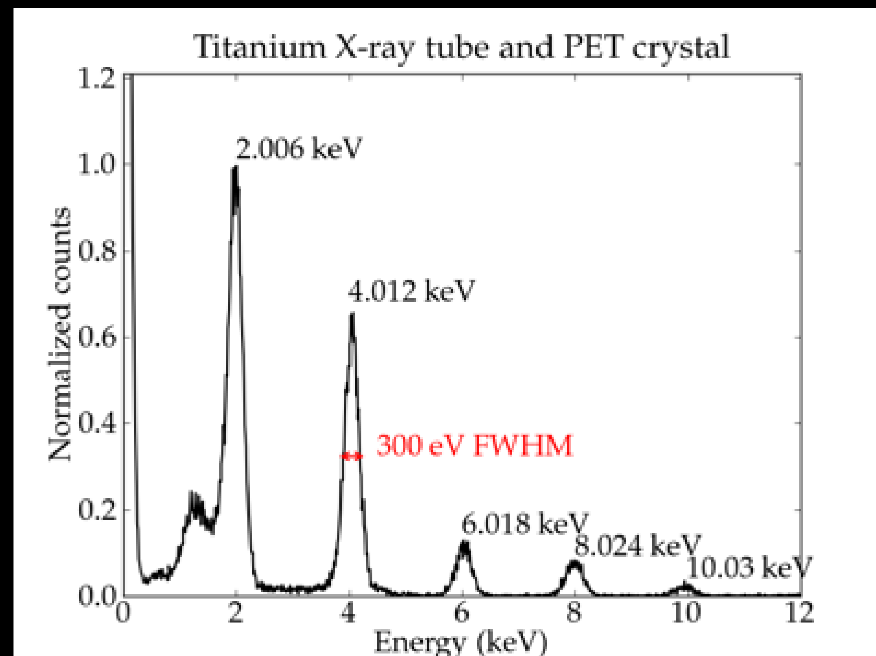


LOFT Baseline

Thickness	450 μm
Monolithic Active Area	76 cm^2
Drift time	<5 μs
Single-channel area	0.3 cm^2

Current Operating SDD Prototype (53 cm^2)
Measured Spectroscopy Performance

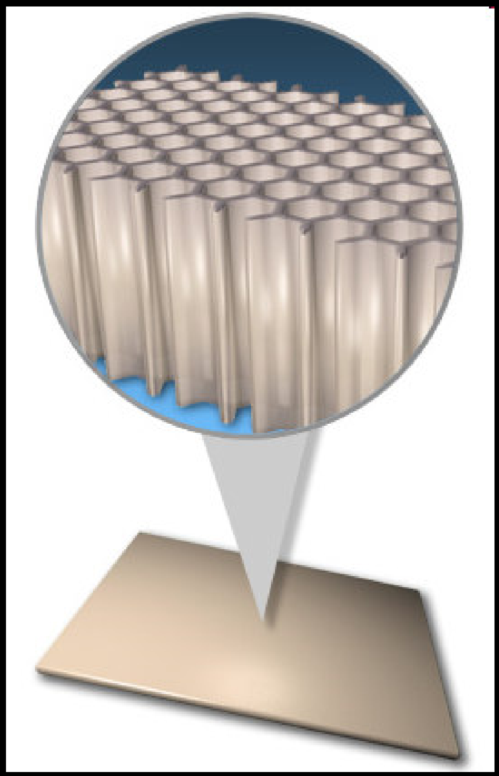




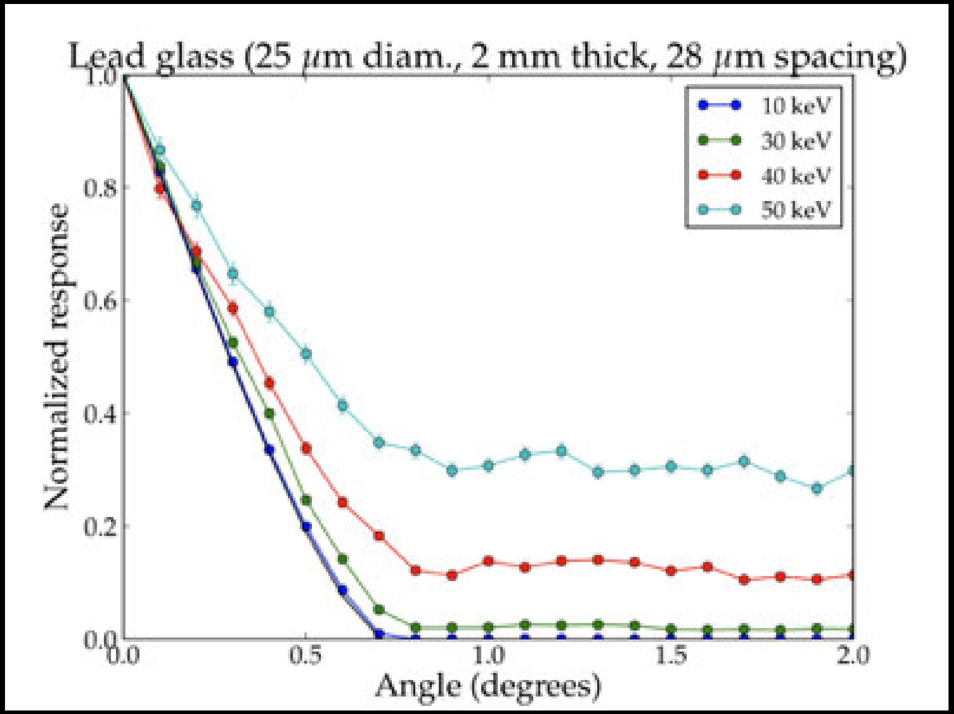
8 discrete read-out channel prototype - Room Temperature

Capillary-plate Collimator

Lead-glass microcapillary plates are commercially available. Customization possible. LOFT baseline: FOV to ~43' FWHM (2 mm thickness, 25 μm hole dia, 28 μm pitch, Open Area Ratio ~80%). Heritage: Microchannel Plates (e.g., Chandra).



Collimation vs Energy:
GEANT Montecarlo simulations

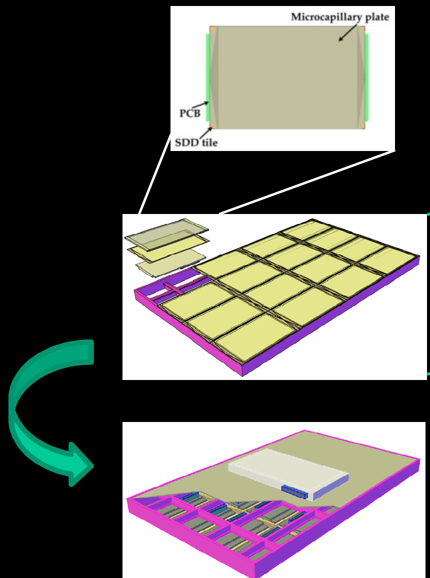


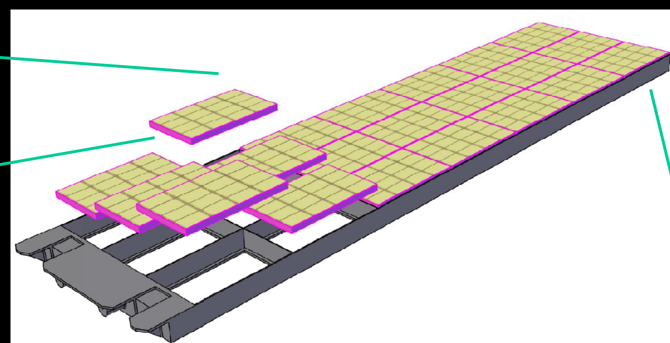
Mission Implementation

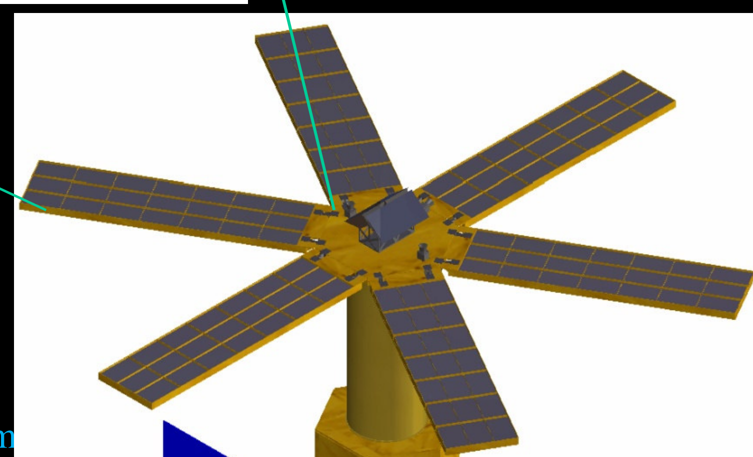
The Large Area Detector (LAD) for LOFT

A fully modular and redundant approach:

16 independent detectors per Module
21 independent Modules per Detector Panel
6 independent Detector Panels per LAD

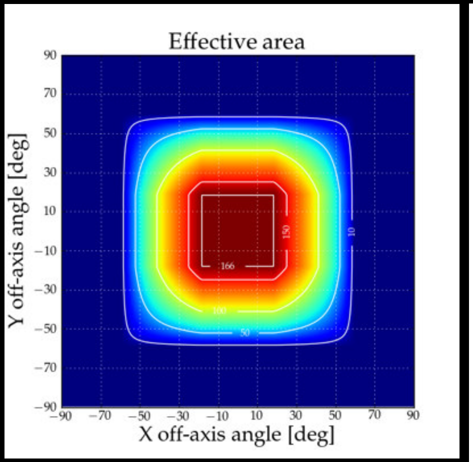


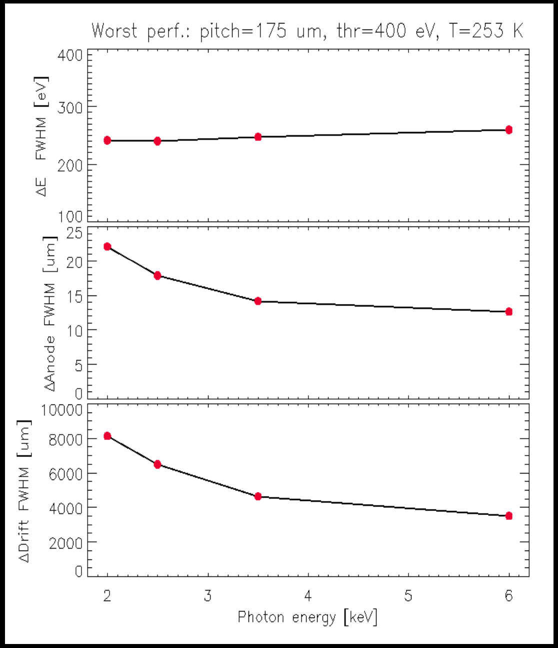


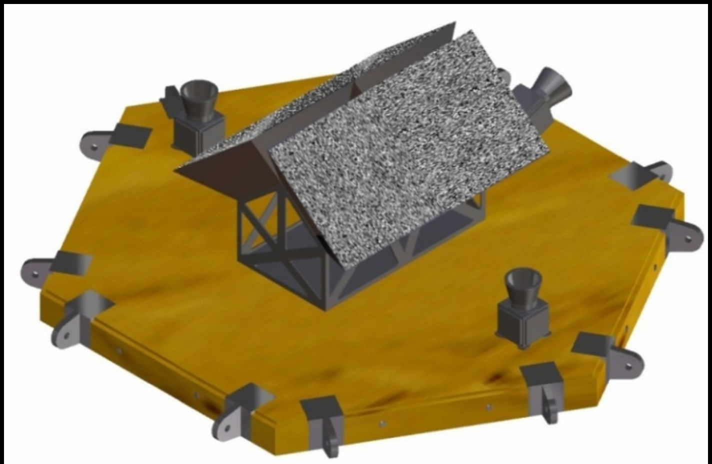


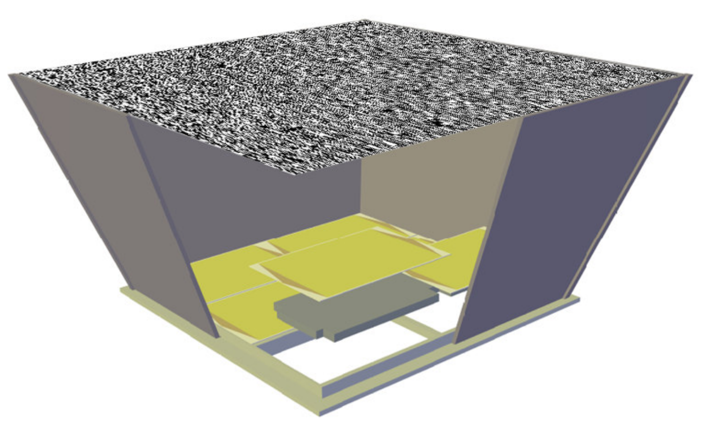
The Wide Field Monitor for LOFT

Based on the same type of Si detectors as the Large Area Detector but finer pitch (~200 μm): asymmetric angular resolution of each orthogonal camera.





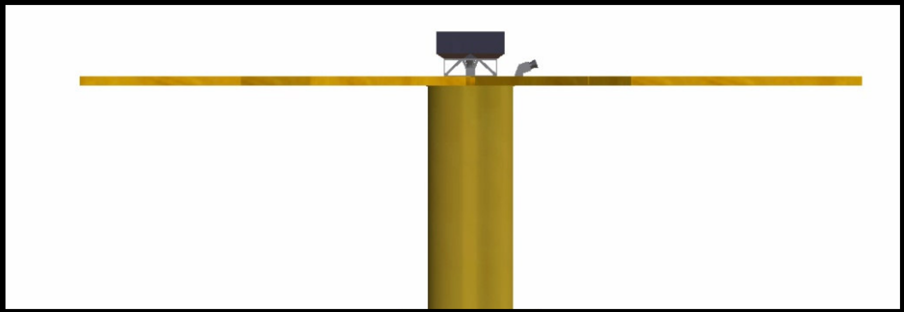


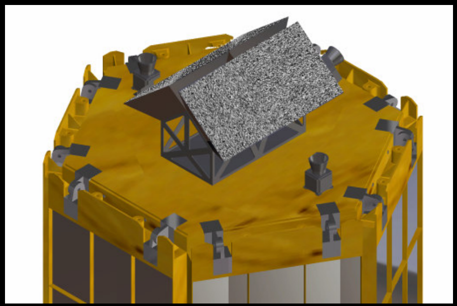


4 units (2 pairs)
FoV, each unit:
0.4 sr FC
2.9 sr PC

The WFM Baseline Specifications

Parameter	Single Unit	Overall WFM
Energy	2-50 keV	2-50 keV
Geometric Area	400 cm^2	1600 cm^2
Energy Resolution FWHM	< 350 eV	< 350 eV
Field of View Fully Coded	0.40 sr	0.80 sr
Partially Coded	2.90 sr	3.95 sr
Zero Response	118°	154°
Angular Resolution	5’ x 2°	5’ x 5’
Point Source Location Accuracy (10σ, 1D)	< 1’ x 40’	< 1’x1’
On-axis sensitivity at 5σ in 1 s	610 mCrab	430 mCrab
On-axis sensitivity at 5σ in 50 ks	2.7 mCrab	1.9 mCrab
Total Power (w/margins)		14 Watts
Total Weight (w/margins)		37 kg

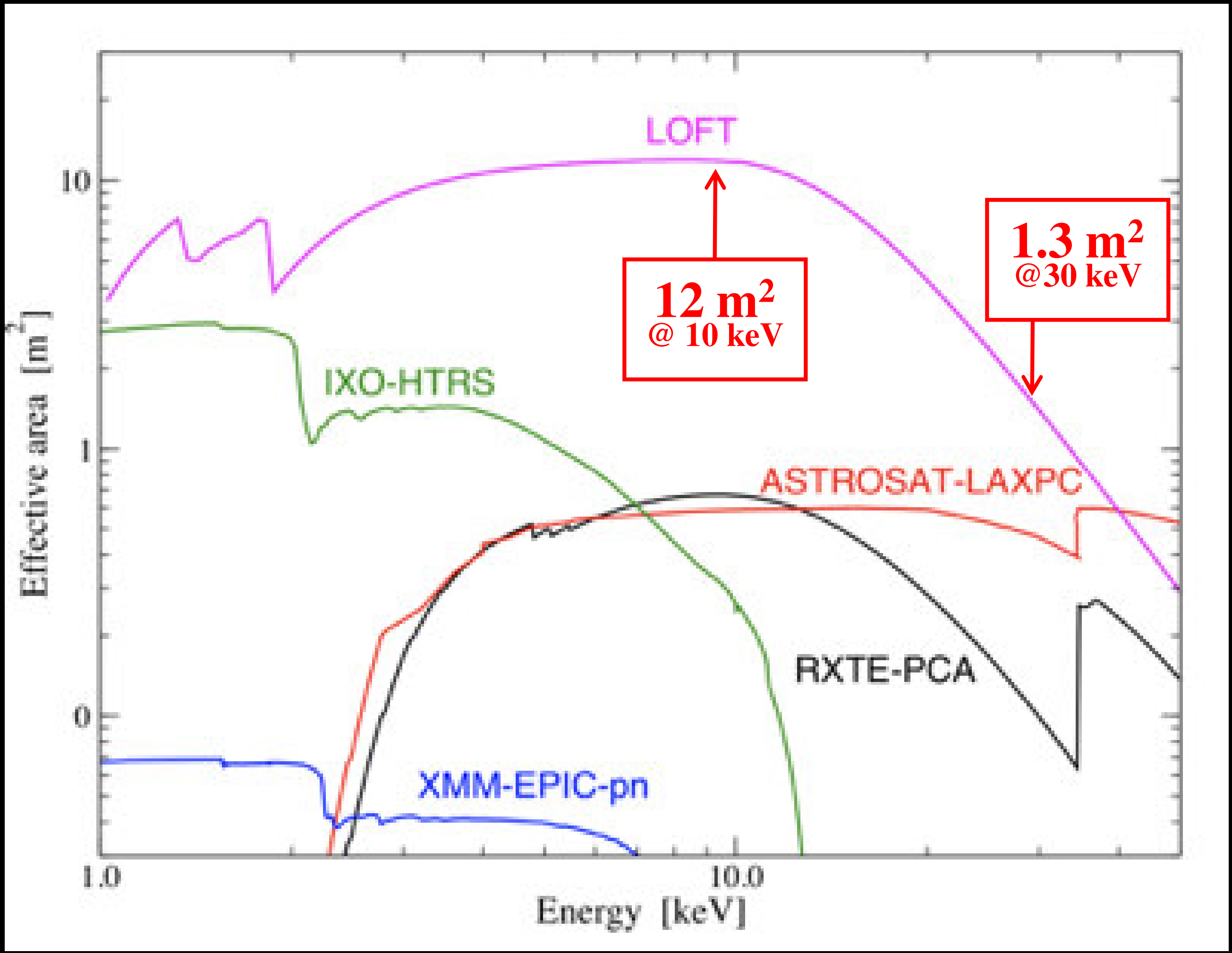




The LOFT Baseline Overview

Detector	450 μm thick SDD
Energy Range	2-30 keV (2-50 keV extended range)
Field of View	43 arcmin
Geometric Area	18 m^2
Effective area (@8 keV)	12 m^2 (20x RXTE/PCA)
Energy Resolution	<260 eV (<200 eV for 40% of the area)
Time Resolution	5 μs
Crab Count Rate	3×10^5 cts/s
Deadtime	<0.5% for 1 Crab
Sensitivity	1 mCrab/1s
Supporting Experiment:	Wide Field Monitor (4 sr)
Satellite Mass	~1800 kg
Telemetry	<700 kbps
Orbit	Low-Earth (Vega launcher)

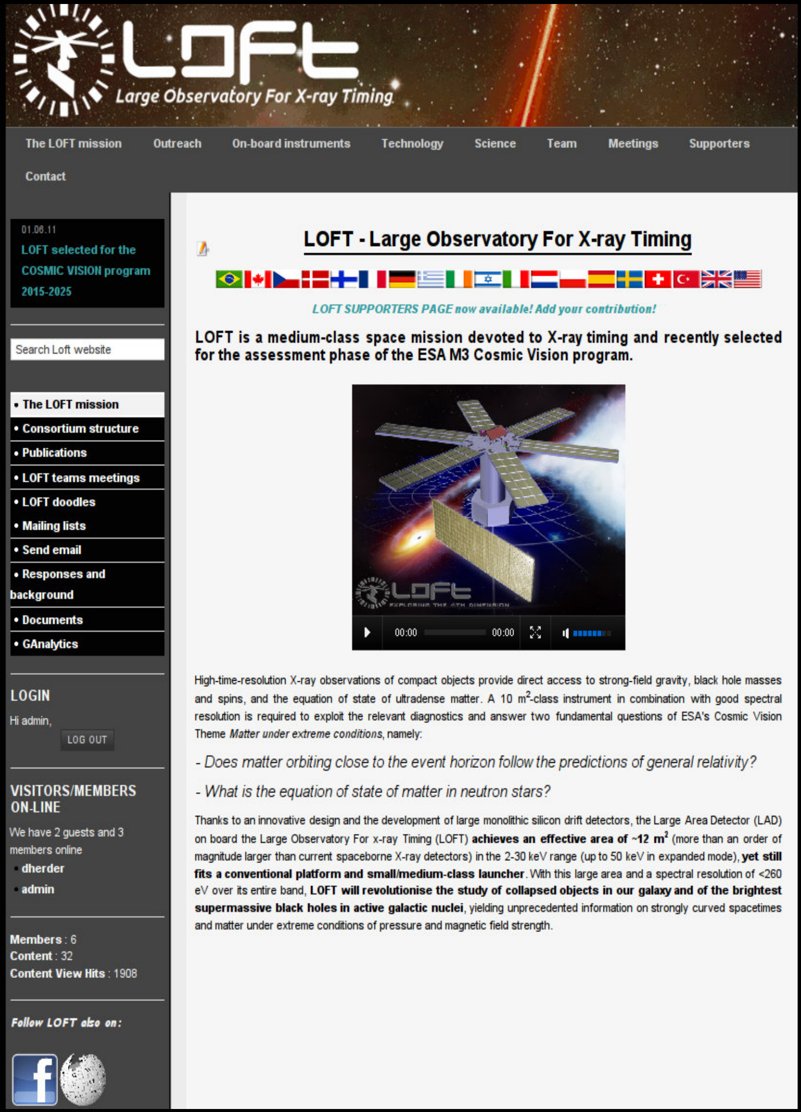
LOFT in context



The New LOFT Web Page

http://www.isdc.unige.ch/loft

- Mission info
- Simulation Tools
- Project status updates
- Public Outreach



LOFT International Support Team:
loft.webmaster@gmail.com

The First LOFT International Science Workshop

Amsterdam, Science Park

26-28 October 2011

Stay Tuned on Public Announcements and LOFT Web Page

http://www.isdc.unige.ch/loft


LOFT is a simple mission, relying on solid hardware heritage, offering both breakthrough and observatory science.
LOFT is one of the 4 missions selected by the ESA WGs and SSAC as a candidate CV-M3
http://www.isdc.unige.ch/loft
Thank you