LOFT prospects for Terrestrial Gamma-ray Flashes studies

Large Observatory For X-ray Timing

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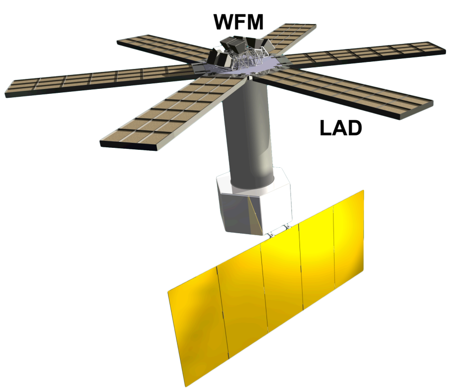
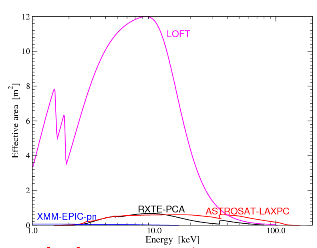
The Large Observatory For x-ray Timing (LOFT) http://www.isdc.unige.ch/loft is an astrophysics space mission designed to study the neutron star structure and equation of state of ultra-dense matter and to explore the conditions of strong-field gravity.
LOFT was selected by ESA as a candidate medium class mission scheduled for launch in 2022 and is currently in the assessment phase. Although LOFT primary scientific objective is the timing of astrophysical x-ray sources, it will be also suitable to detect Terrestrial Gamma-ray Flashes (TGFs) as one of its many secondary scientific targets. Most of the TGF measurements carried out so far are hampered by dead-time effects because of the large TGF brightness. LOFT, specifically designed for timing studies, has a fine detector granularity and an excellent control of dead-time, therefore it will help to unveil the fine structure of bright TGFs light curves at 10 microseconds time scale.

A. The LOFT mission



WFM (Wide Field Monitor)
- Coded aperture imaging experiment
- Large-area Silicon Drift Detectors
- Field of view 180°x90° FWZR
- Energy range 2-50 keV (+ 50-80 keV extension)
- Energy resolution <500 eV @6 keV
- Effective area 1850 cm^2
- Angular resolution <5 arcmin
- **Main objective: transient source monitor for the LAD**

LAD (Large Area Detector)
- Collimated experiment
- 2016 large-area Silicon Drift Detectors for a total sensitive area ~15 m^2
- Field of view 1°x1° obtained by X-ray microchannel plate collimators
- Energy range 2-80 keV
- Energy resolution <260 eV @6 keV
- Effective area 10m^2 @8 keV, 1m^2 @30 keV
- Time resolution ~7μs
- Dead time < 1% @ 250 kHz
- **Main objective: timing study of astrophysical sources**

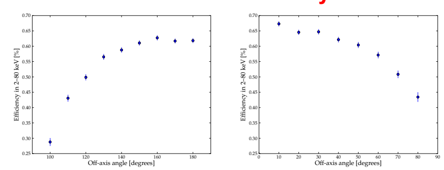


Key mission parameters
- Low Earth Orbit 600 km altitude, <5° inclination
- ESA medium class (M3) mission, launch 2022
- Mission lifetime >4 year

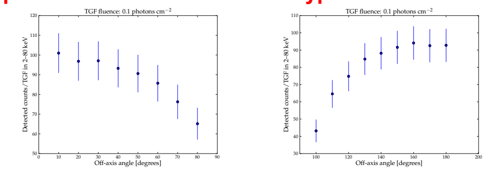
B. LOFT TGF detection capabilities

We used an empirical spectrum based on Monte Carlo simulations of a TGF source at 50g/cm^2 atmospheric depth, corresponding to a production altitude of ~21km, propagated to satellite altitude through the atmospheric layers (Dwyer and Smith, GRL, 32, L22804, 2005, and J. Dwyer, private communication). This spectral model gives the best fit results when applied to the RHESSI TGF cumulative spectrum. Simulations were carried out in GEANT-4 using the full LOFT mass model.

Detection efficiency



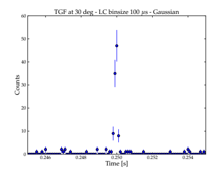
Expected number of counts for typical RHESSI TGF



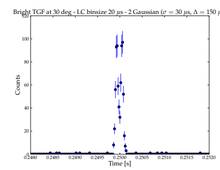
C. Time profile

LOFT has a fine detector granularity and an excellent control of dead-time, therefore it will help to unveil the fine structure of TGFs light curves at 10 microsecond time scale, especially for bright events which are mostly affected by dead time in current detectors.

Single pulse, fluence 0.1 cm^{-2}, t_{50} = 100μs



Double pulse, fluence 0.7 cm^{-2}, 2x t_{50} = 40μs, 150 μs Δt



Detection rate	Min. fluence (cm^{-2})	Min. counts in LOFT
1 / day	0.021	19
1 / 10 days	0.12	112
1 / 30 days	0.29	261

(For an occulatation fraction 0.3)

D. Expected TGF detection rate

Minimum detectable fluence in RHESSI (Grefenstette et al., JGR, 114, A02314, 2009):
$F_{0,RH}$ = 15 / 256 cm^2 = 0.058 cm^{-2}

RHESSI detection rate: R_{RH} = 0.42 TGF/d

Minimum detectable fluence in LOFT during:
- Earth occultation (2.4 bkg counts/500μs)
$F_{0,LO}$ = 19 / 900 cm^2 = 0.021 cm^{-2}

- observation of 100 mCrab source (12.5 bkg counts/500μs)
$F'_{0,LO}$ = 43 / 900 cm^2 = 0.048 cm^{-2}

Assuming a power law distribution with spectral index λ=2.3 ± 0.2 for the TGF intensity at satellite altitude (Østgaard et al., JGR 117, A03327, 2012) the LOFT to RHESSI expected relative rate is:
R_{LOFT} / R_{RH} = 3.7 [-0.6; +0.9] (occultation)
R'_{LOFT} / R_{RH} = 1.3 [-0.2; +0.3] (observation)

Correcting for the time fraction spent in Earth occultation (0÷0.3) and the different latitude band (x2.2) we expect to detect **1.1 ÷ 1.8 TGFs/day** with fluence above 0.02 cm^{-2}