Les organisateurs:

➔ « Pourrais-tu nous parler des instruments qui produisent des alertes X/γ dans la décennie à venir ? »

TS2020 workshop
Montpellier, 2018/06/04

Stéphane Schanne
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Institut de recherche sur les lois fondamentales de l'Univers

X/Gamma-ray Events
Trigger Machines
for the 203rd decade
(2021-2030)

TS2020 workshop
Montpellier, 2018/06/04

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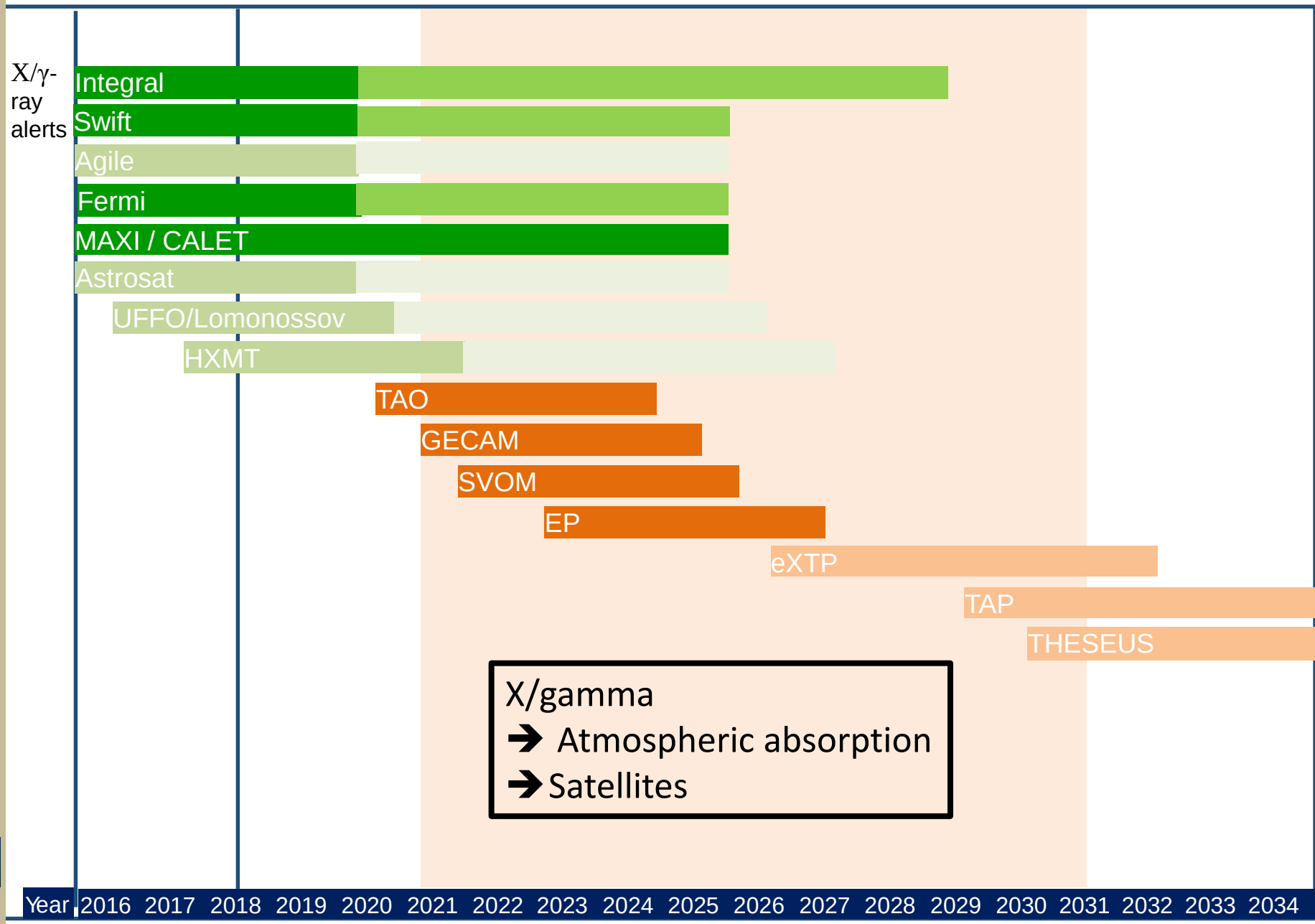
Missions d'alertes X/gamma de la 203ème décennie



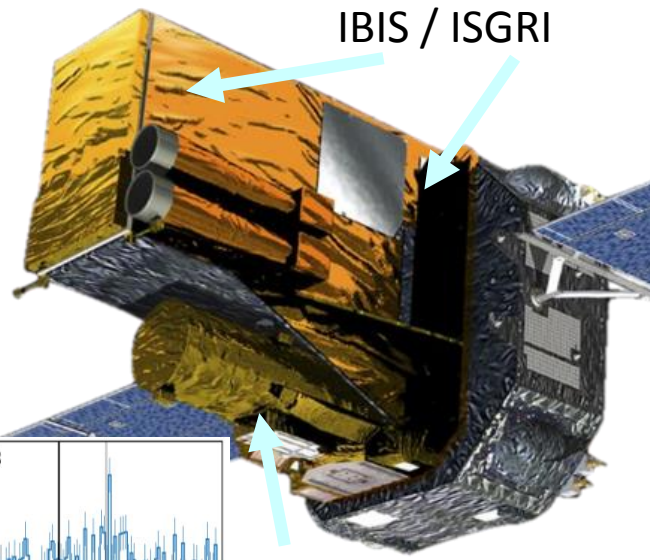
X/Gamma-ray Events
Trigger Machines
for the 203rd decade

in operation

Integral: International Gamma-Ray Astrophysics Laboratory

Launched : 16 October 2002

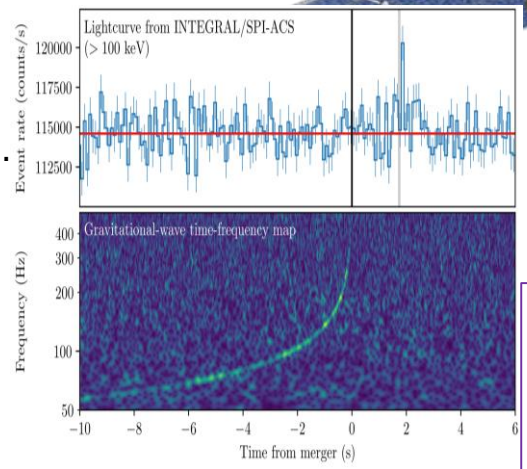
Instruments
IBIS / ISGRI (CdTe) and PICSIT (CsI) + coded mask
SPI (Ge) + SPI/ACS (BGO) + coded mask
Jem-X, OMC



INTEGRAL Burst Alert System (IBAS):
automatic software for near real time detection of GRBs by on ground analysis of the INTEGRAL data received at INTEGRAL Science Data Center (ISDC).

Developed by IASF Milano, MPE Garching & ISDC.

Data from IBIS / ISGRI and SPI / ACS.



- GRB rate ~ 1 / month (IBIS / ISGRI)
  ~ 0.5 / day (SPI / ACS)
- Delay ~20 – 30 s

IBAS trigger types:
- POINTDIR for robotic telescopes
- SPIACS detected by the SPI ACS (no position)
- WAKEUP first alert with position information
- REFINED subsequent messages with better info
- OFFLINE results of interactive analysis
- WEAK low significance triggers

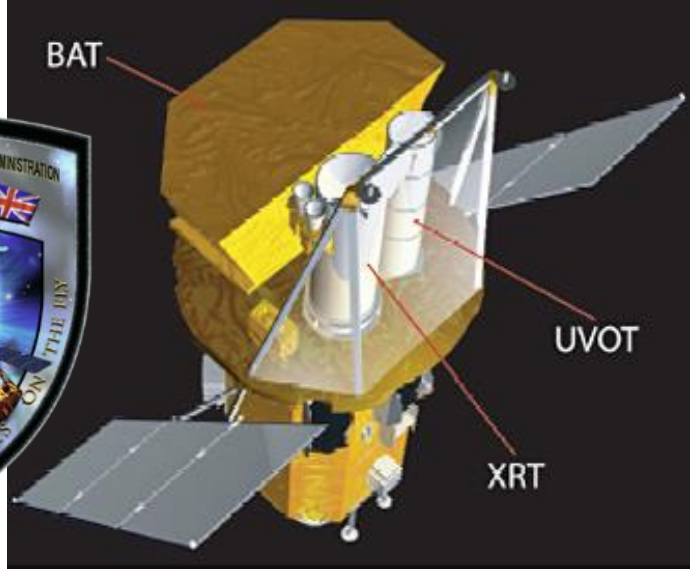
Integral approved for 2 more years

Reentry in Feb 2029

ISGRI:
E = 15 keV ~ 1 MeV
FoV = 29°x29°
Loc = 2 – 3 arcmin

SPI/ACS:
E > 100 keV
FoV ~ 4 pi
Loc: none

Swift: Neil Gehrels Swift Observatory



Launched : 20 November 2004

Multi-wavelength observatory (gamma, X, UV).
Rapid identification and multiwavelength follow-up of gamma-ray bursts (GRBs) and their afterglows.

- ~90 GRBs discovered per year
- <90 s slew: reaction time for onboard follow-up
- 0.5-5 arcsec positions for almost every GRB
- Results publicly distributed within seconds

Rate ~ 90 GRB/yr
Slew in ~1 min
Loc < 5 arcsec

*** Burst Alert Telescope (BAT)**
Coded mask telescope (CdZnTe)
GSFC + LANL (flight software)
Oboard trigger: Count-rate + Image trigger (thresh> 25 keV)

*** X-ray Telescope (XRT)**
After slew: images, spectra & light curves: flaring and long-term decay of afterglow.
XRT built using existing JET-X hardware (MOS CCD)
Penstate, Brera & Uni Leicester

*** UV/Optical Telescope (UVOT)**
Copy of the XMM-Newton Optical Monitor (OM).
Penstate and MSSL.
Images, spectra (via grism) and light curves after slews.

Onbaord fuel (orbit maneuvers) until ~ 2026

BAT: Eff area: 5200 cm^2
E = 15 ~ 150 keV
FoV ~ 2 sr
Loc = 2 – 3 arcmin
Rate > 90 GRB / yr

XRT: Eff area: 120 cm^2 at 1.5 keV
E = 0.3 ~ 10 keV
FoV ~ 23 x 23 arcmin
Loc ~ 5 arcsec
Rate ~ 90 GRB / yr

UVOT: Loc ~ 0.5 arcsec
6 colors: 180-600 nm

→ for brightest UV/optical afterglows, redshift via Lyman-alpha cut-off.

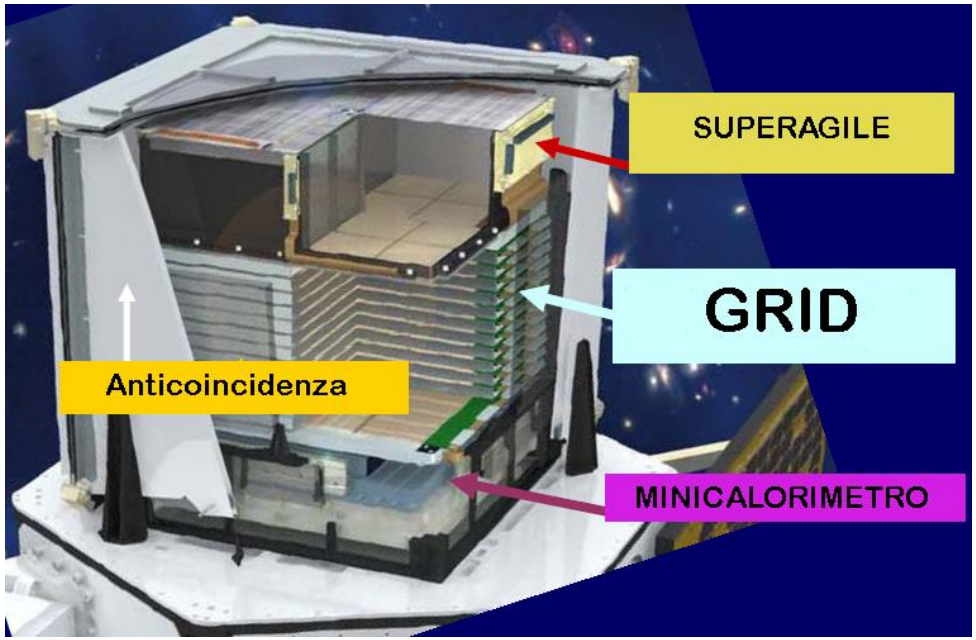
Agile: Astro-Rivelatore Gamma a Immagini Leggero

Launched : 23 April 2007

Instruments
- GRID: silicon tracker
- Super-AGILE : enhances detection and imaging capabilities in X-rays (10-40 keV).

Super-AGILE: additional plane of four Silicon square units positioned on top of the GRID Tracker plus an ultra-light coded mask structure with a top absorbing mask at the distance of 14 cm from the Silicon detectors. Main goals : simultaneous gamma-ray and hard X-ray detection of astrophysical sources, optimal source positioning (1-3 arcmin)

Fast gamma-ray burst and transient alert, on board trigger capability.



GRB triggers since 2013 ?

Fermi: Fermi Gamma-ray Space Telescope

Launched : 11 June 2008

Gamma-Ray Large Area Space Telescope (GLAST)
Instruments:

LAT (Large Area Detector)
- 20 MeV – 300 GeV
- Pair conversion telescope (e^+ e^-)
- 18 Si layers (tracker → direction)
- 8 CsI layers (calormieter → energy)

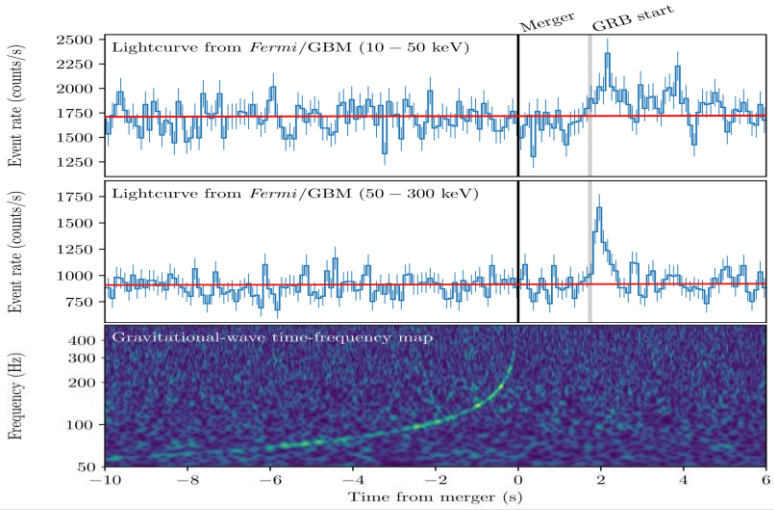
➔ High energy sources (AGN, Pulsars…)

Rate < 1 GRB / month

GBM (GLAST Burst Monitor)
scintiallators: photon energy and time
- 12 NaI (8 keV – 1 MeV, 126 cm^2 each, FoV~2pi)
- 2 BGO (150 keV – 30 MeV)

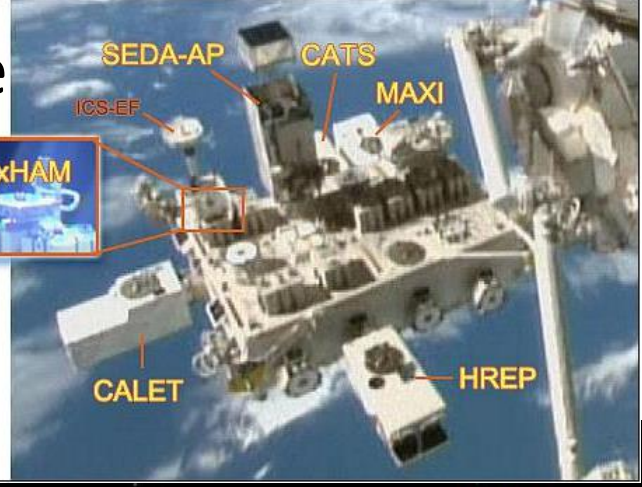
➔ Transient events, variable sources

Rate ~ 240 GRB / yr
Loc > 3 ~ 15° (det ratios)



<u>GBM On-board trigger</u> (count-rate increase),
- different time scales, threshold > ~50 keV
- Alerts via TDRSS to GCN (~30 s delay)
- some Spacecraft slew for LAT.

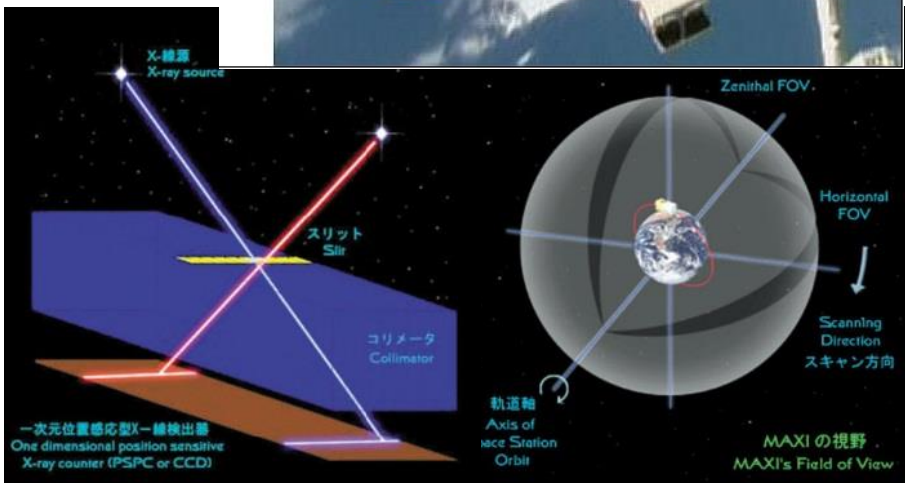
Maxi : Monitor of All-sky X-ray Image



Launched : August 2009,installed on ISS/JEM

All-sky X-ray scanner: sensitive X-ray slit cameras

MAXI monitors the X-ray variability once every 96 minutes for more than 1,000 X-ray sources covering entire sky on time scales from a day to a few months.



Overview

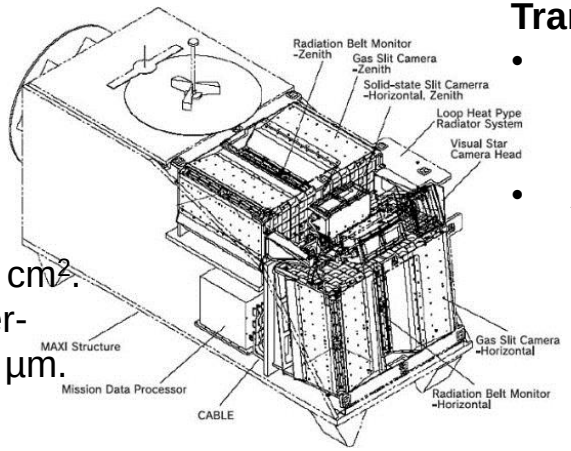
- Slit camera ~2% of sky at once.
- E = 0.5 ~ 30 keV
- 1D X-ray detector : determine 1 direction of source
- Motion of ISS: other position when source in FoV.
- ISS orbit every 96 min = 1 full sky scan.

Gas Slit Camera (GSC)

12 gas proportional counters, total 500 cm^2, 2-30 keV, 1D position: 10µm anodes.

Solid-state Slit Camera (SSC)

2 cameras. 16 CCD chips per camera, total 200 cm^2. CCD: X-ray 0.5 to 10 keV, made in Japan, peltier-cooled, 1024x1024 pixels per CCD, pixel:24x24 µm.



Transient X-ray sources

- Ground detection (30 s delay when real-time ISS link available, ~16 h/day)
- Alerts on GCN (Position and detection confidence in the notices, Spectrum in circulars)

Loc ~< 10 arcmin

Successor: iWF-MAXI is currently targeted to begin observation at the ISS by 2019

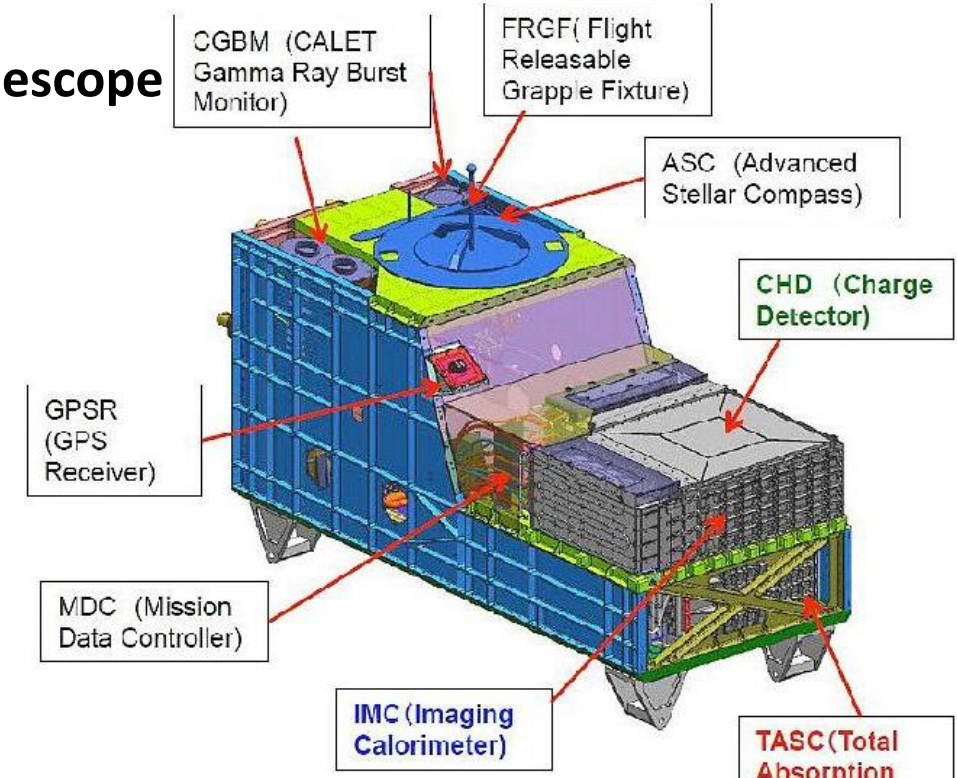
Calet: CALorimetric Electron Telescope

JAXA

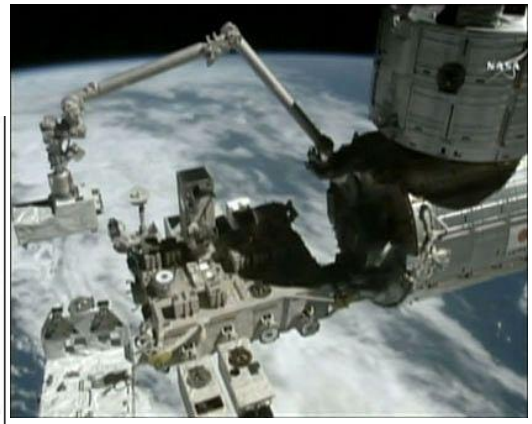
Launch : August 2015, ISS/JEM

CALET: astrophysics mission of JAXA searching for signatures of dark matter and measuring cosmic-ray electron spectrum.

CGBM (CALET Gamma-ray Burst Monitor) can detect short duration gamma ray bursts, x-ray flashes to longer burst events. Time resolution of 62.5 ms. Two components:
The SGM (Soft Gamma-ray Monitor) **uses a single Bismuth Germanate scintillator** (BGO) of size 102 x 76 mm, covering an energy range of 100 to 20 000 keV.
The HXM (Hard X-ray Monitor) **uses two Lanthanum Bromide scintillators** (LaBr3) 12.7 mm thick and 66x79 cm in diameter. Energy range of 7 to 1000 keV.

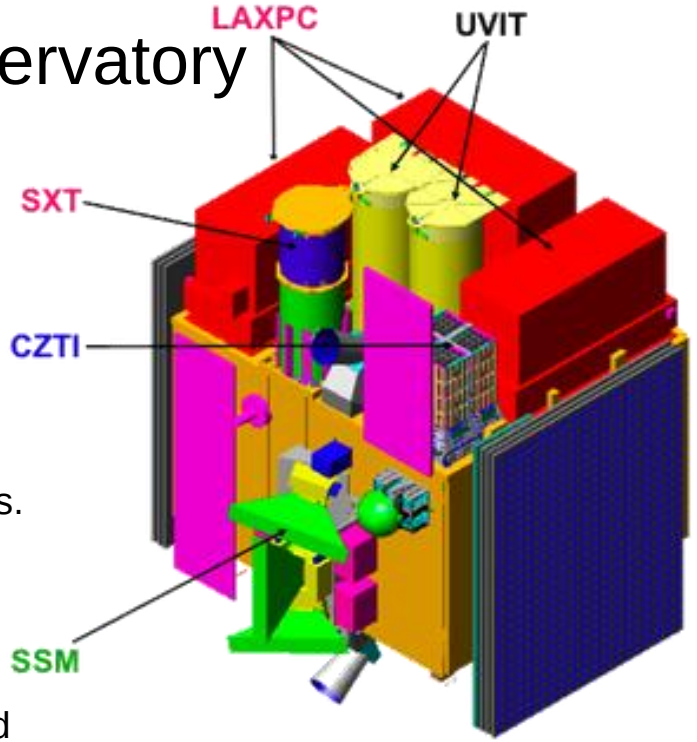


- CALET's CGBM (CALET Gamma-ray Burst Monitor) has measured the light curves of 30 GRB's as of July, 2016.
- 5-year observations are planned.



Astrosat: India's 1st X/γ space observatory

Not many news…



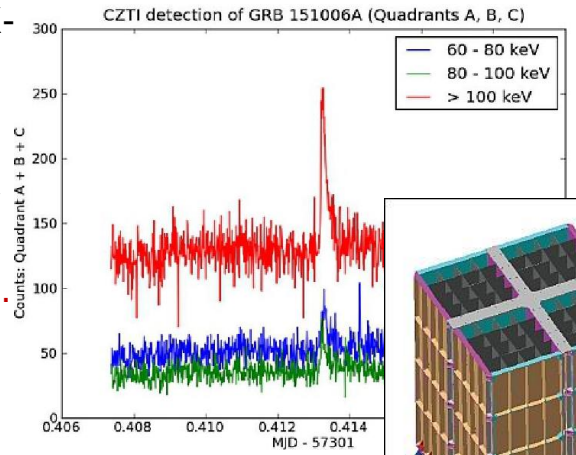
Launched : 28 September 2015

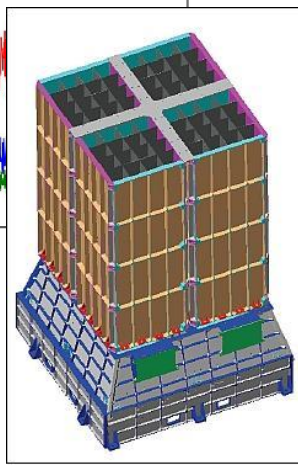
Launch Vehicle: PSLV-C30/AstroSat MISSION / ISRO

Deeper insight into the astrophysical processes occurring in the various types of astronomical objects of the universe, through the visible, Ultraviolet and X-rays coming from distant celestial sources.

Instruments:

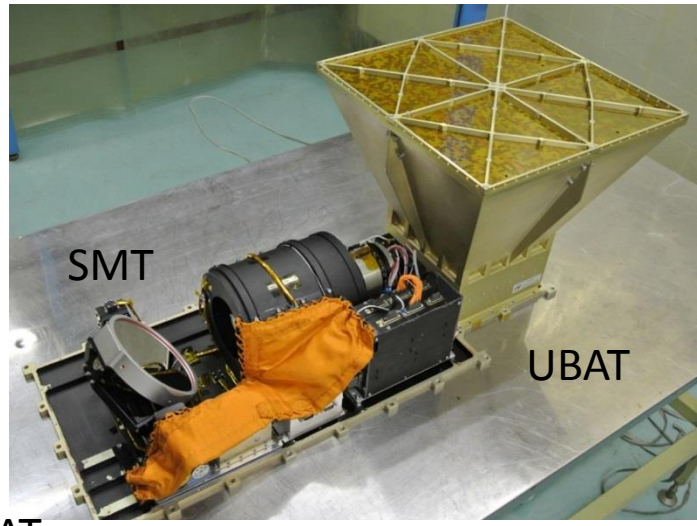
* **The Ultraviolet Imaging Telescope (UVIT)**
* **Soft X-ray Telescope (SXT)** 0.3-8 keV
* **Large Area X-ray Proportional Counter (LAXPC)**, is designed for study the variations in the emission of X-rays from sources like X-ray binaries, Active Galactic Nuclei and other cosmic sources.
* **Scanning Sky Monitor(SSM)**, sky scan, long term monitoring of bright X-ray binaries and transients: Slit camera, 1D positionning.
* **Cadmium Zinc Telluride Imager (CZTI)**, functioning in the X-ray region, extends the capability of the satellite to sense X-rays of high energy in 10-100 keV range. ➔ GRB detection and (sometimes) loc.





Energy range	10 - 150 keV, up to 1 MeV (photometric)
Energy resolution	5% @ 100 keV
Pixel size, number of pixels	2.4 mm x 2.4 mm (5 mm thick)
Number of pixels	16384
Geometric area	1024 cm^2
FOV (Field of View)	6º x 6º (10-100 keV) (defined by collimator)
	17º x 17º (> 100 keV) (defined by coded mask housing)
Angular resolution	8 arcmin (< 100 keV)

Uffo: Ultra-Fast Flash Observatory Pathfinder



Launched : 28 April 2016
onboard Lomonosov russian university satellite (UFFO: Korea, Russia, Denmark)

News are hard to find: Nov 2017 paper “UBAT of UFFO/Lomonosov: The X-Ray Space Telescope to Observe Early Photons from Gamma-Ray Bursts”:

Laboratory confirmation was achieved for the algorithm correcting for the continual drift of detector pixels resulting from satellite movement. Calculations of excess in count rates and the imaging of X-ray sources together with a real time correction of satellite movement (drift correction) was successfully implemented through the onboard FPGA IC chips of the UBAT system. This is the first time ever utilization of FPGAs, which permit the much faster implementation of X-ray imaging algorithms (less than a second) and lower power consumption (less than 2 W).

The UBAT aboard the UFFO/Lomonosov went through a careful initial check-up process in orbit in preparation for operation with actual GRB triggers. During the early phase of instrument calibration, we have measured and understood the diffuse X-ray background and examined a series of trigger schemes through the adjustment of programmable instrument parameters.

UBAT

Field of view	~1.8 sr (partially coded)
Detector	6 × 6 MAPMT+YSO
Energy-band	5–200 keV
Angular resolution	1.07°
Pointing accuracy	≤10 arcmin accuracy for >7σ
Number of detector pixels	48 × 48
Pixel size	2.88 × 2.88 × 3 mm^3
Detection area (Effective area)	191.1 cm^2 (165.5 cm^2)
Energy resolution	2 keV (FWHM) at 60 keV
Detection efficiency	99.4% at 30–50 keV
Passive shielding composition	0.2 mm W + 3.0 mm Al
Passive shielding absorption	100% at 4–50 keV
Coded mask pattern	W alloy of 1 mm thickness
Coded mask size	400 × 400 × 1 mm^3
Mask to Detector	280 mm
Weight	10.5 kg

Insight-HXMT: China's 1st X/γ space observatory

Hard X-ray Modulation Telescope

IHEP Beijing

Launched : 15 June 2017

- China's 1st X-ray astronomy sat.
- Selected in 2011, launched from Jiuquan
- Cir. Orbit 550 km, incl. 43° weight 4500 kg
- Design lifetime 4 yrs

Core Science

- Galactic plane scan and monitoring of weak & short transient sources in 1-250 keV
- Pointed observations: High stat. long term obs. of bright sources and XRB outbursts
- Multi-wavelength obs. with other telescopes
- GRBs, GW EM, FRB, etc.

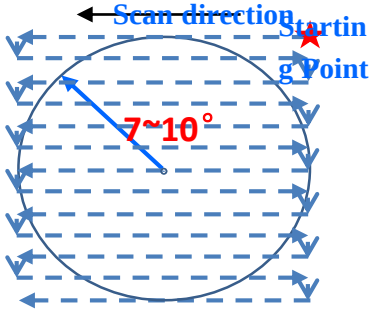
HE: ~ 200 GRB/yr
Alerts ? Loc ?

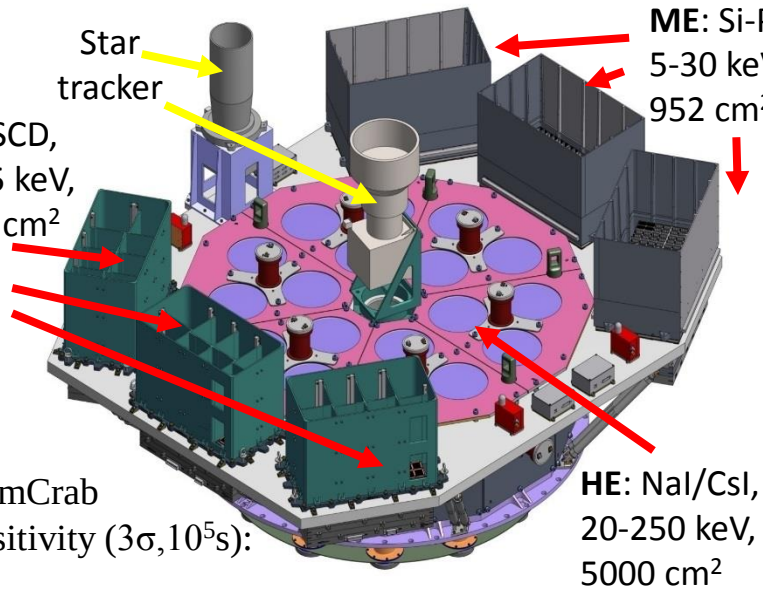
ToO

- Alerts from GCN, HXMT scan
- Rescheduling within >4h (on 8 orbits/day)

Observation modes

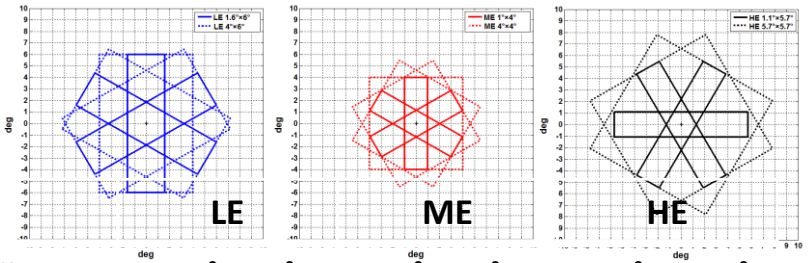
- Scanning duration : 2 h ~ 5 days
  - radius: 7~10°
  - step: 0.1~1°
  - vel. 0.01~0.06 °/s
- Pointed 1 orbit – 20 dy
- GRB mode (for HE):
  - CsI : 3 MeV
  - monitor GW error box





0.5 mCrab sensitivity ($3\sigma, 10^5$s):

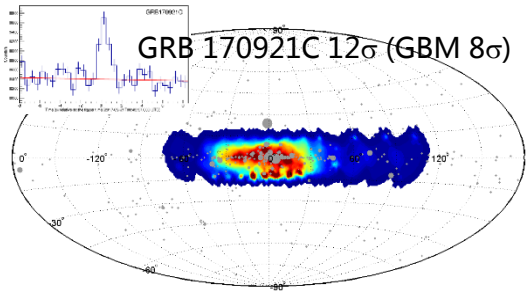
Fields of view of the different Collimators



	LE	ME	HE
Small FoV	1.6° x 6°	1° x 4°	1.1° x 5.7°
Large FoV	4° x 6°	4° x 4°	5.7° x 5.7°

Results (first 6 months)

- GPS (>200 scans)
- > 30 pointed sources
- Detected >30 GRBs
- Joinded IPN
- GW 170817 follow-up



X/Gamma-ray Events
Trigger Machines
for the 203rd decade

in preparation

Svom: Space Variable Objects Monitor

NAOC Beijing, CEA Saclay
CNSA/CAS + CNES/CEA,CNRS

Launch : 2021 ?

Adopted by CNAS/CAS/CNES (Phase C: jan 2017)

Sat ~ 950 kg, payload 450 kg, 3 axis stabilized, LEO
650 km, 28° incl. Chinese Platform, Launcher LM2C

Scientific objectives

- Trigger on all known types of GRBs (~ 200 in 3 years)
- Provide fast, reliable and accurate positions of GRBs
- Spectrum and light curve (from visible to MeV) of GRB
- Slew ➔ Afterglows and arcsec positions of GRBs
- Redshift indicators for GRBs

- **Core Program (CP)** : follow-up ECLAIRs triggers (about 70 GRB/yr) ~ 25% of time
- **Targets of Opportunity (ToO)**: 1 / dy: external triggers: multi-wave (LSST, SKA, CTA…) or multi-msg (GW, neutrino) ~15% of time
- **General Program (GP)**: AGN, TDE, Galactic sources (CV, XRB, pulsars) …~ 40 % of time

***ECLAIRs** caméra X/g*

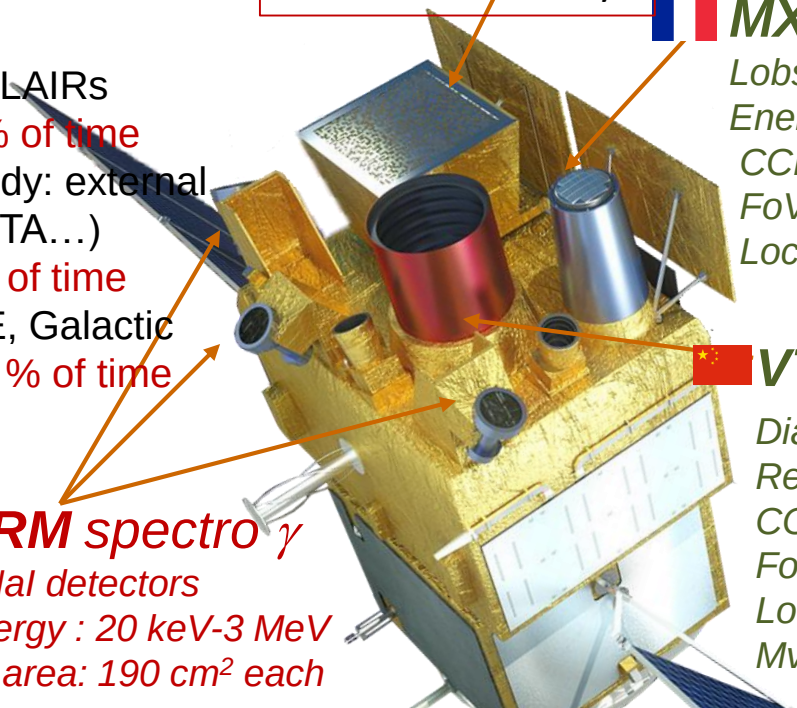
6400 pixels CdTe, énergie 4 – 150 keV
Eff. Area ~ 1000 cm² (before masking)
Coded mask (Ta, 0.6 mm)
Large FoV (2sr ~ 6600 deg², 90 x 90 °)
Localization <12 arcmin

***Onboard Trigger** (4-120 keV)*

- *count-rate 10 ms ~ 20 s + loc.*
- *Image trigger 20 s ~ 20 min*

➔ ***Automatic satellite slew (3~5 min)***
➔ ***Alert to ground (via VHF ~ 30 s)***

Rate ~ 50-75 GRB/yr



***MXT** Télesc. X*

Lobster Optics
Energy : 0.2 – 10 keV
CCD-X 256x256
FoV 1 deg²
Loc <1 arcmin

***VT** Télesc. Vis.*

Diameter 40 cm
Red and Blue band
CCDs 2Kx2K
FoV 26x26 arcmin
Loc ~ arcsec
Mv ~ 22.5 (in 300 s)

+ ground visible:

***GWAC** prompt*
***2 GFTs** f.-up*

***GRM** spectro γ*

3 NaI detectors
Energy : 20 keV-3 MeV
Eff area: 190 cm² each

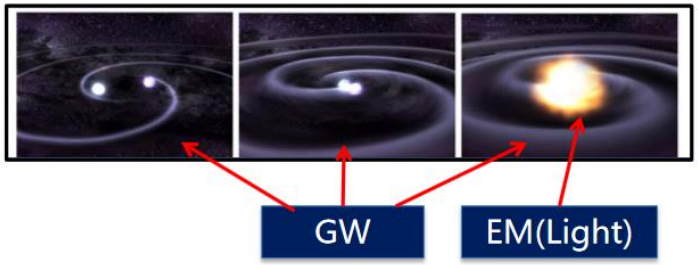
Gecam: Gravitational Wave Electromagnetic Counterpart All-sky Monitor

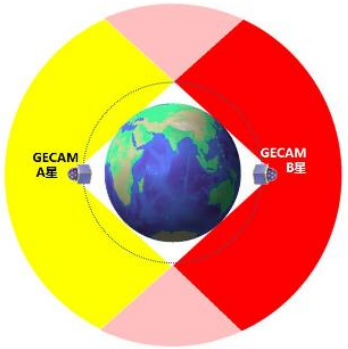
IHEP Beijing

Launch : 2021 ?

Adopted by CAS (in 2018)

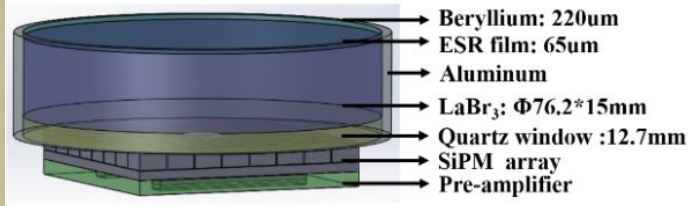
- Core Science: GW ElectroMagnetic counterpart (GWEM)



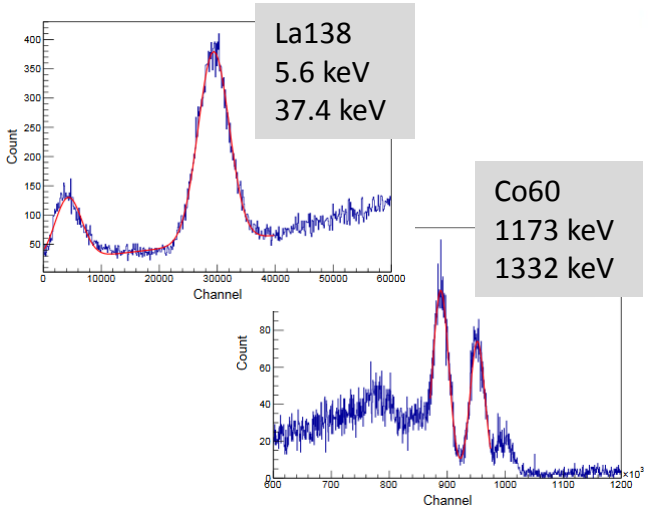


Detector

La Br_3



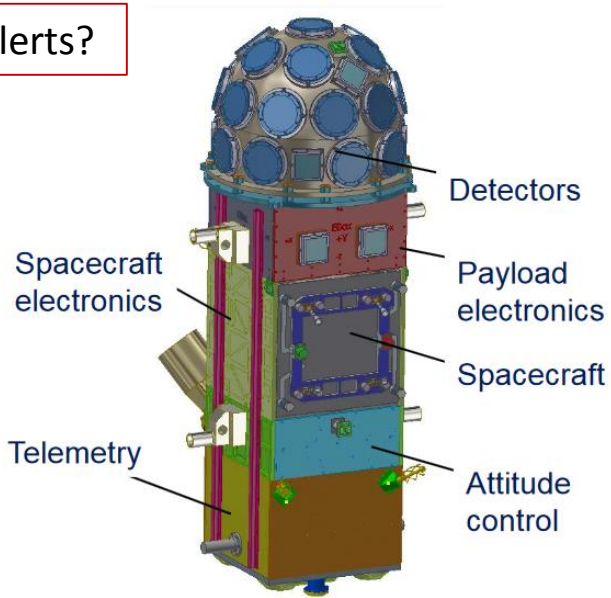
- Independent confirmation of GW event
- Accurate localization, host galaxy, redshift
- Astrophysical content of the GW source
- GW+EM, Cosmology, fundamental physics



- Features

Trigger? Alerts?

  - FOV : 100% all-sky
  - Sensitivity : ~2E-8 erg/cm^2/s
  - Localization : ~1 deg (1-sigma, stat.)
  - Energy band : 6 keV – 5 MeV
- Planned to launch in the 2021
- Joint observation with LIGO & Virgo when they reach best sensitivity



Tao: Transient Astrophysics Observatory (former ISS-Lobster)

Launch : 2021 ?

TAO esson#2: NASA GSFC

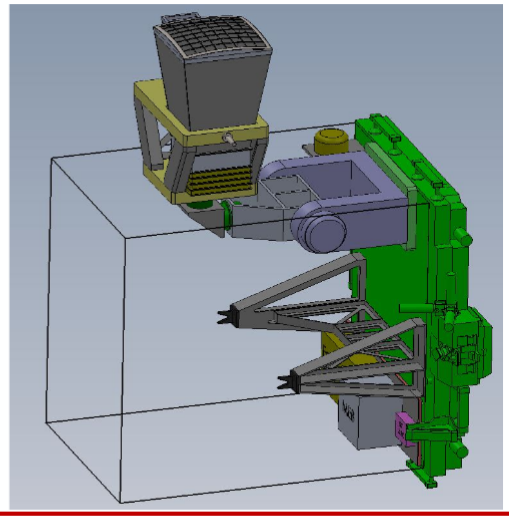
everything is transient

- ISS payload on the Express Logistics Carrier
- ISS provides
  - "free" launch
  - "free" power
  - continuous uplink/downlink 80% of the time, with sufficient data rates
- Instruments
  - Gamma-ray Transient Monitor (GTM)
  - Wide-field Imager (WFI)

Operations:

- Sky survey/ToOs (incl. GW)
- Rapid autonomous repointing to new transients

3 year mission (5 year goal)

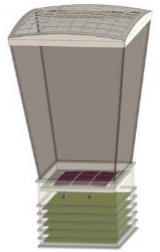


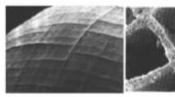
- 2x *Fermi*-GBM built-to-print NaI detectors (scintillators + PMTs)
- FoV ~2π
- Energy range 10 keV - 1 MeV
- Onboard triggering in 3 timescales and 3 energy ranges
- Localization not possible

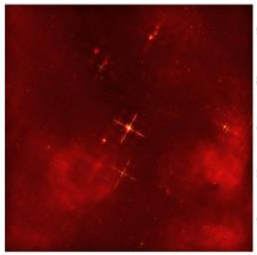
Source Type	WFI source rate (/yr)
NS-NS GW counterparts	1-3
NS-BH GW counterparts	8-14
ccSN shock breakout	1
TDEs	24 (15 non-jetted, 9 jetted)
AGN (monitored)	600 (weekly) 100 (daily)
Blazars (monitored)	300 (weekly) 80 (daily)
Stellar Super Flares	10-100
Novae	0.3
Thermonuclear Bursts	110
Long GRBs	80
High-z GRBs (z≥5)	2
Short GRBs	10

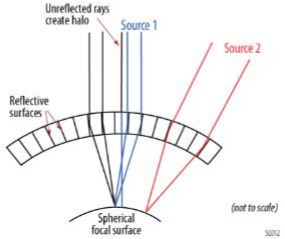
- Multi-channel (lobster) optics with CCD focal plane (Angel 1979)
- 45 cm focal length
- FoV: 20° x 20°
- Sensitivity: 10^{-10} erg cm^{-2} s^{-1} (20 s), 10^{-12} erg cm^{-2} s^{-1} (10 ks)
- Energy Range: 0.3-5 keV
- Centroid: ~1 arcmin

FoV ~ 0.12 sr









EP: Einstein Probe

NAOC Beijing

Launch : 2022 ?

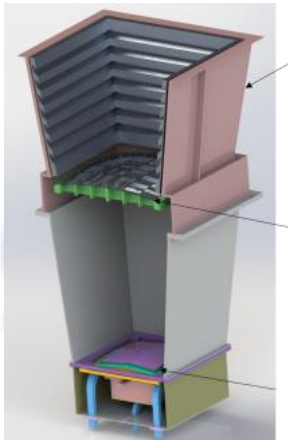
Adopted by CAS (end 2017)

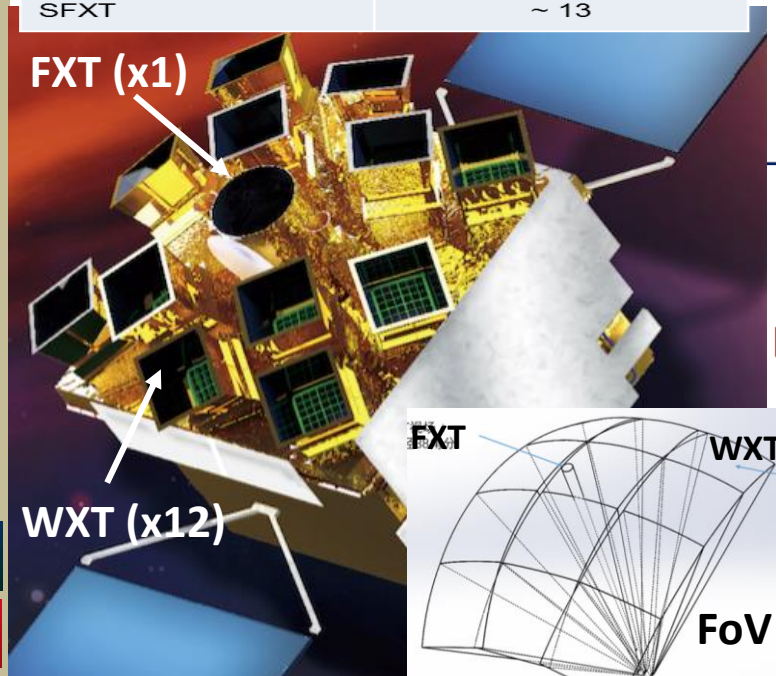
Type of events	Detections /yr
TDE	30-120 (onset/peak)
TDE with jets	20 - 40
SN shock breakout	7
GRB z > 6 (8)	7 (3)
magnetars	1
X-ray flash	~ 10
Low-luminosity GRB	< 8
SFXT	~ 13

- EP is an explorer-class mission
  - Dedicated to time-domain astronomy
  - For all-sky monitoring to discover and study high-energy transients and variability in the soft X-ray band
- Science Objectives
  - Carry out systematic survey of soft X-ray transients and variability of X-ray sources at unprecedented sensitivity and high cadence
  - Discover otherwise quiescent Black holes at all astrophysical mass scales and other compact objects by capturing their transient flares
  - Detect and localize the electromagnetic-wave sources of gravitational-wave events by synergy with gravitational-wave detectors

Payloads

- Wide-field X-ray Telescope (WXT)
  - X-ray optics: lobster-eye MPO; FoV~ 3600 square degrees
  - Detector: CMOS array
- Follow-up X-ray Telescope (FXT)
  - X-ray optics: Wolter-1 type; FoV ~ 38 arcmin
  - Detector: CCD





Features

FoV 1 sr

- Large Field of View 3600 sq. deg.; grasp: ~10,000 deg^2.cm^2
- Monitoring: soft X-ray band: 0.5-5keV
- Sensitivity: > 1 order of magnitude higher than those in orbit
- Good angular resolution (~5 arcmin) and positioning accuracy (<1 arcmi
- Autonomous follow-up (<10 arcsec localisation; 0.3-10keV)
- Fast alert data downlink and (possible) fast uplink (ToO)

eXTP: extended Timing and Polarimetry mission

IHEP Beijing
INAF Rome

Launch : 2025 ?
Selected for CAS Phase A+ (in 2018)

Overview:

- eXTP = XTP + LOFT. 3 March 2018: kick off of extended Phase A/B by CAS (440 Myuan until end 2020).
- CAS + European consortium (ASI lead). + possible ESA MoO.
- Launch > 2025, 4.5 tons, low Earth equatorial orbit, LM7

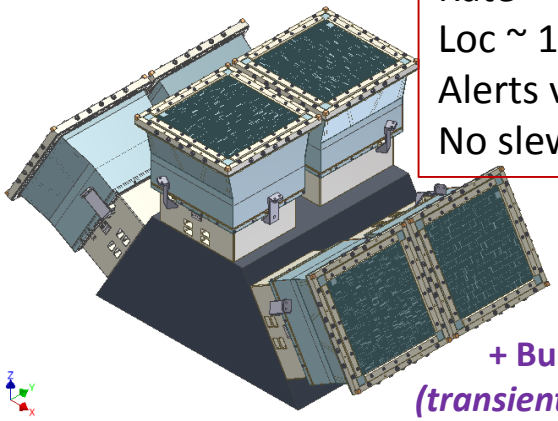
Science goals:

- Fundamental physics (Dense matter, strong gravity, extreme magnetism), observing neutron stars (M vs R relation, nuclear matter EOS, QCD), black holes (GR) & magnetars (QED).
- Time domain X-ray astro. of compact objects and transients

Wide Field Monitor (WFM)

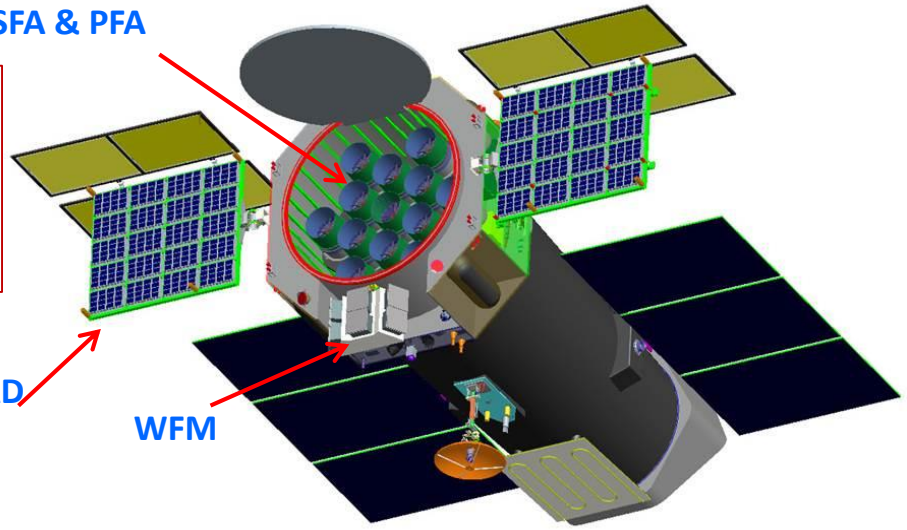
- 3 units (6 cam): 1.5 D coded mask
- Detectors: SDD
- Energy range: 2-50 keV
- Energy resolution: 500eV@6keV
- Field of view: 3.2 sr
- Angular resol.: 5′, Location: 1′
- Time resol.: 10μs
- Sensitivity: 4mCrab (1day)
- Effective area: 170cm²@6keV

Payload	Configuration	Eff. area (m²)	Timing res. (μs)
Spectroscopic Focusing Array (SFA)	9 telescopes	0.54m²@1keV	10
Large Area Detector (LAD)	40 modules	3.4m²@2-10keV	10
Polarimetry Focusing Array (PFA)	4 telescopes	700cm²@2keV	500
Wide Field Monitor (WFM)	6 cameras	3.2 Sr （FOV）	10



Rate ~ 120 GRB/yr
Loc ~ 1 arcmin
Alerts via VHF of Baidu
No slew

+ Burst Alert System
(transient events trigger)



Theseus: Transient High-Energy Sky and Early Universe Surveyor

Launch : end of 203rd decade? 2032 ?

Selected for ESA M5 Phase A (in 2018, 3 competitors)

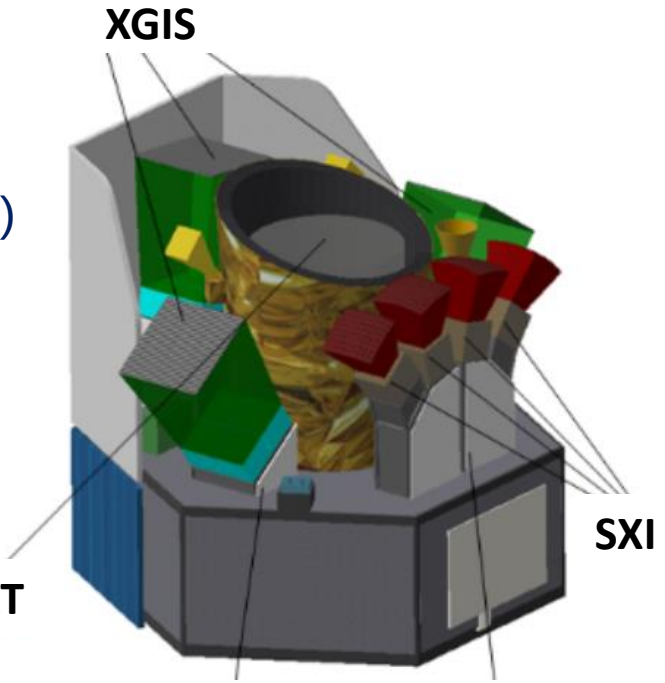
Italy-led European collaboration, with interest of USA, China, Brazil

Core science:

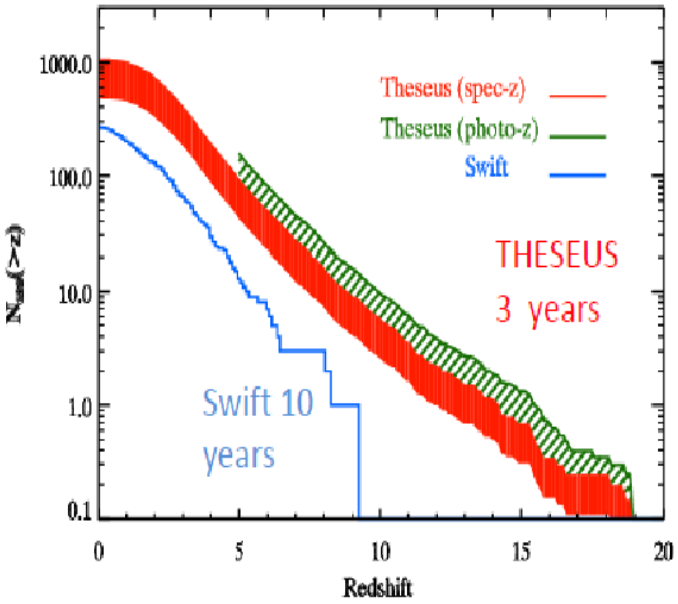
- GRB population in the 1st Gyrs (Early Univ., reionization era)
- Deep monitoring of the soft X-ray transient Universe
- GW/multi-messenger and time domain astro, in synergy with aLIGO/aVirgo, LISA, ET, Km3NET, LSST, E-ELT, SKA, CTA...
- Athena synergy: repoint Athena (6hr) to interesting GRB afterglows for simultaneous X-ray and NIR spectroscopy

Instruments:

- **Soft X-ray Imager (SXI, 0.3 – 6 keV):** 4 sensitive lobster-eye telescopes, total FoV ~1sr, location accuracy < 1-2 arcmin
- **X-Gamma rays Imaging Spectrometer (XGIS, 2 keV – 20 MeV**): 3 coded-mask X-gamma ray cameras using bars of Silicon diodes coupled with CsI crystal scintillators, total FoV of ~1sr, overlapping SXI, 5' source location accuracy;.
- **InfraRed Telescope (IRT, 0.7 – 1.8 μm**): a 0.7m class IR telescope with 10'x10' FoV, fast response, imaging & spectro



THESEUS GRB#/yr	All	z > 5	z > 8	z > 10
Detections	387 - 870	25 – 60	4 – 10	2 - 4
Photometric z		25 – 60	4 – 10	2 - 4
Spectroscopic z	156 - 350	10 - 20	1 - 3	0.5 - 1



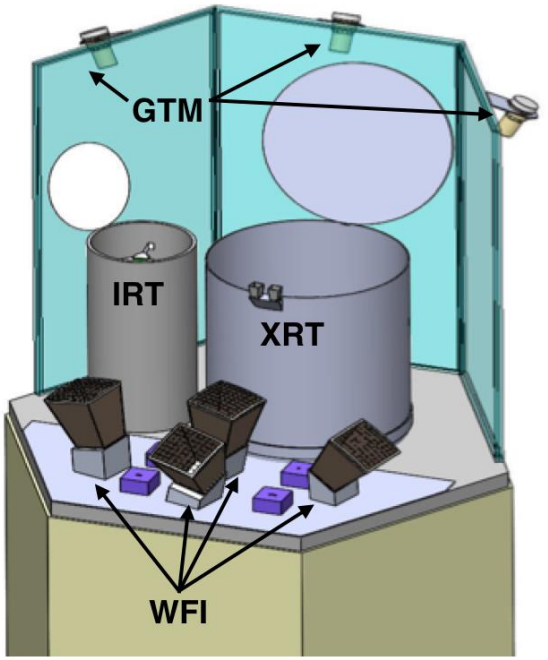
Tap: Transient Astrophysics Probe

NASA GSFC

Launch : end of 203rd decade? 2030 ?

Selected for NASA Probe Concept study (in 2017)

adoption of the mission not before Oct. 2023



Instruments:

- **Wide Field Imager (WFI)** - soft X-ray wide field of view Lobster microchannel optic surveys the sky
- **X-ray Telescope (XRT)** - sensitive crystal silicon, grazing incidence, soft X-ray telescope that follows up and localizes transients and conducts a deep survey
- **InfraRed Telescope (IRT)** - near-IR telescope provides localizations and rapid low-resolution spectroscopy of transients
- **Gamma-ray Transient Monitor (GTM)** - NaI scintillators coupled to PMTs monitoring the sky for transients

Parameter	WFI	XRT	IRT	GTM
Quantity	4-6 Lobster Eye	1 Grazing Incidence	1 near IR	3-12 NaI/PMT
FoV	N x 19°x19° (0.5 sr)	1° diameter	1°x1°	2 π sr
Aperture Diameter	n/a	130 cm; fl=500 cm	70 cm	n/a
PSF/FWHM	8 arcmin	3 arcsec	1 arcsec	n/a
Energy Range	0.3 - 5 keV	0.5-6 keV	0.6 - 2.5 µm	10 keV - 1 MeV
Sensitivity	10^{-11} erg cm^2 s^{-1} (2ks)	$2x10^{-15}$ erg cm^2 s^{-1} (2ks)	23 mag (300 sec)	1 ph cm^{-2} s^{-1}

X/Gamma-ray Events
Trigger Machines
for the 203rd decade

conclusions

Missions d'alertes X/gamma de la 203ème décennie