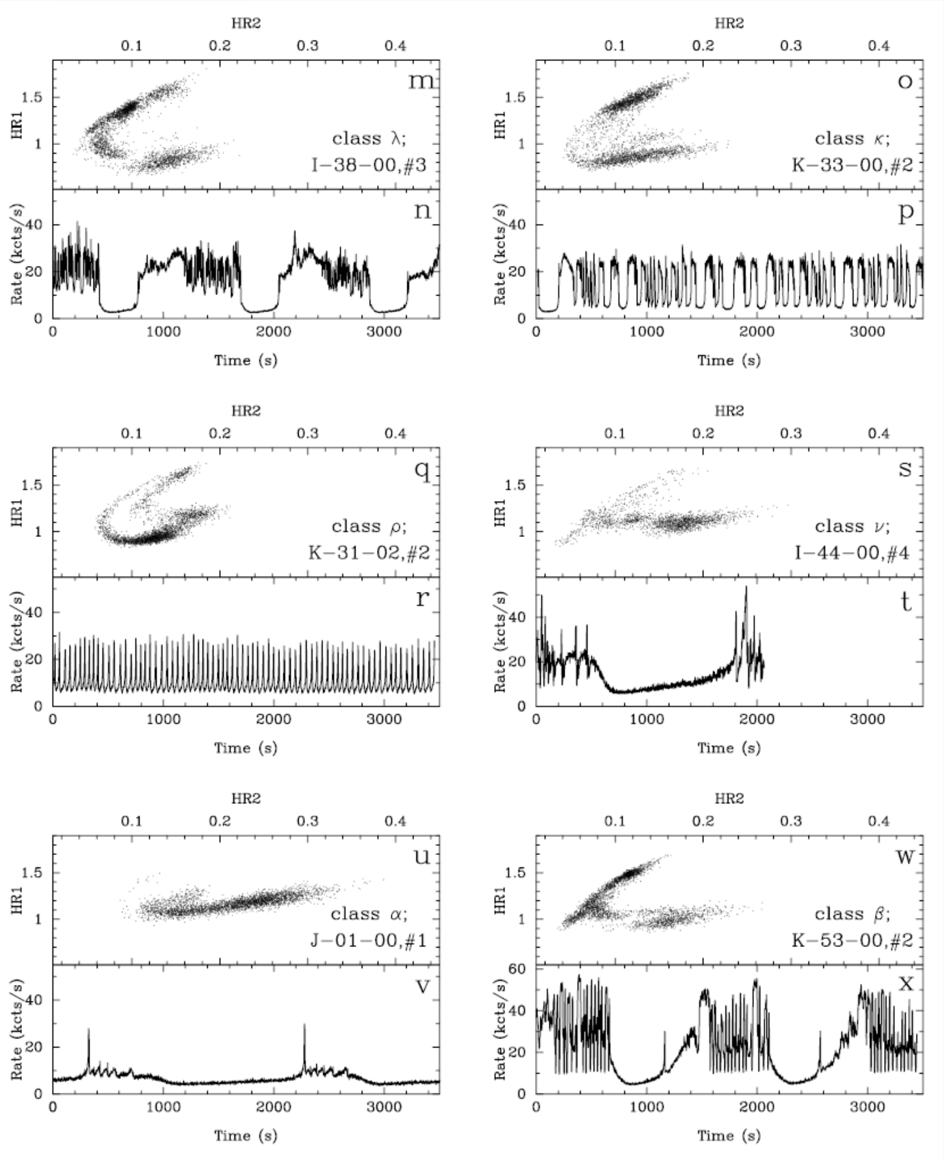
Advances in X-ray Missions

(also thanks to Tomaso…)

Marco Feroci
INAF/IAPS – Rome

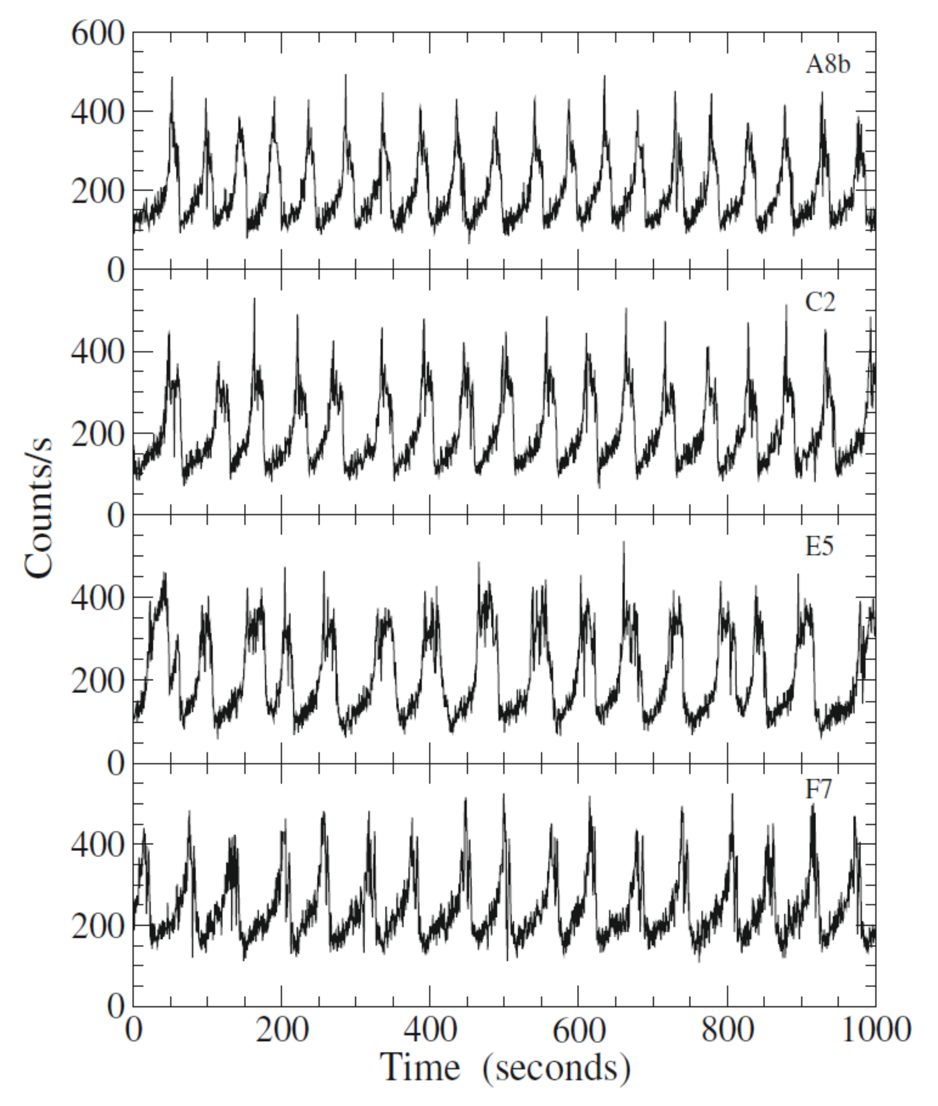
GRS 1915+105 (1994)

GRS 1915+105 AND TOMASO (1997+)



Belloni,…, Mendez, … et al. 2000

GRS 1915+105 AND ME (1998+)



BeppoSAX data, 1998

ME AND TOMASO (1998+)

Astron. Astrophys. 351, 985–992 (1999)

ASTRONOMY AND ASTROPHYSICS

1999

Inner accretion disk disappearance during a radio flare in GRS 1915+105

M. Feroci[1], G. Matt[2], G. Pooley[3], E. Costa[1], M. Tavani[4,5], and T. Belloni[6,7]

Astronomy & Astrophysics

2002

Evidence for a relativistic iron line in GRS 1915+105

A. Martocchia[1], G. Matt[1], V. Karas[2], T. Belloni[3], and M. Feroci[4]

Astronomy & Astrophysics

2003

First INTEGRAL observations of GRS 1915+105★

D. C. Hannikainen[1], O. Vilhu[1,2], J. Rodriguez[3,2], S. Brandt[4], N. J. Westergaard[4], N. Lund[4], I. Mocœur[3], Ph. Durouchoux[3], T. Belloni[5], A. Castro-Tirado[6], P. A. Charles[7], A. J. Dean[7], R. P. Fender[8], M. Feroci[9], P. Hakala[1], R. W. Hunstead[10], C. R. Kaiser[7], A. King[11], I. F. Mirabel[3], G. G. Pooley[12], J. Poutanen[13], K. Wu[14], and A. A. Zdziarski[15]

Astronomy & Astrophysics

2010

The complex behaviour of the microquasar GRS 1915+105 in the ρ class observed with BeppoSAX

I. Timing analysis★

E. Massaro[1], G. Ventura[2], F. Massa[2,3], M. Feroci[4], T. Mineo[5], G. Cusumano[5], P. Casella[6], and T. Belloni[7]

Astronomy & Astrophysics

2012

The complex behaviour of the microquasar GRS 1915+105 in the ρ class observed with *Beppo*SAX

II. Time-resolved spectral analysis

T. Mineo[1], E. Massaro[2], A. D'Ai[3], F. Massa[4,5], M. Feroci[6], G. Ventura[4], P. Casella[7], C. Ferrigno[8], and T. Belloni[9]

2013

Astronomy & Astrophysics

The complex behaviour of the microquasar GRS 1915+105 in the ρ class observed with *Beppo*SAX

III. The hard X-ray delay and limit cycle mapping★

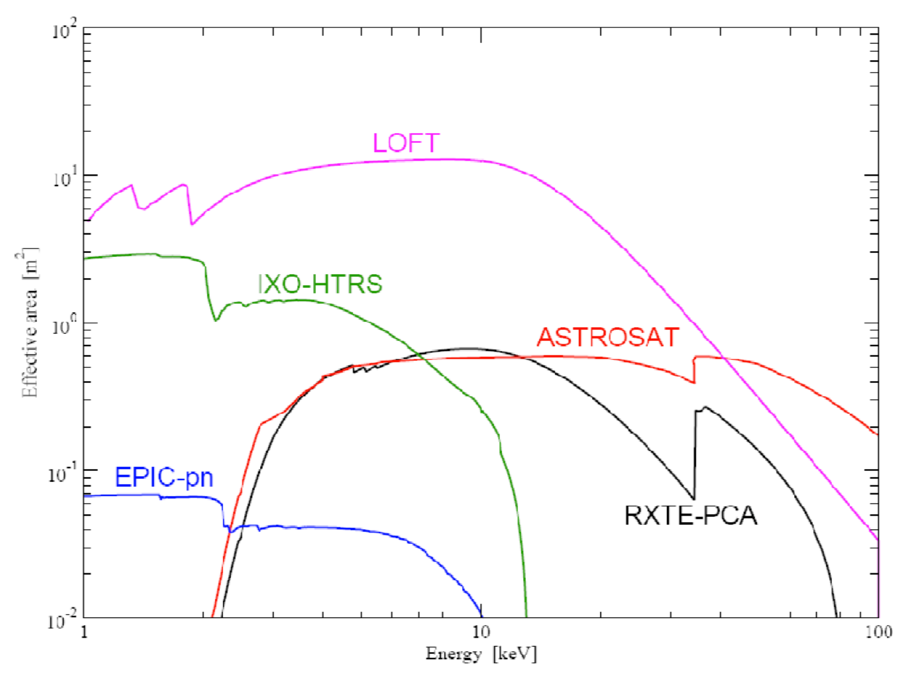
F. Massa[1], E. Massaro[2], T. Mineo[3], A. D'Aì[4], M. Feroci[5], P. Casella[6], and T. Belloni[7]

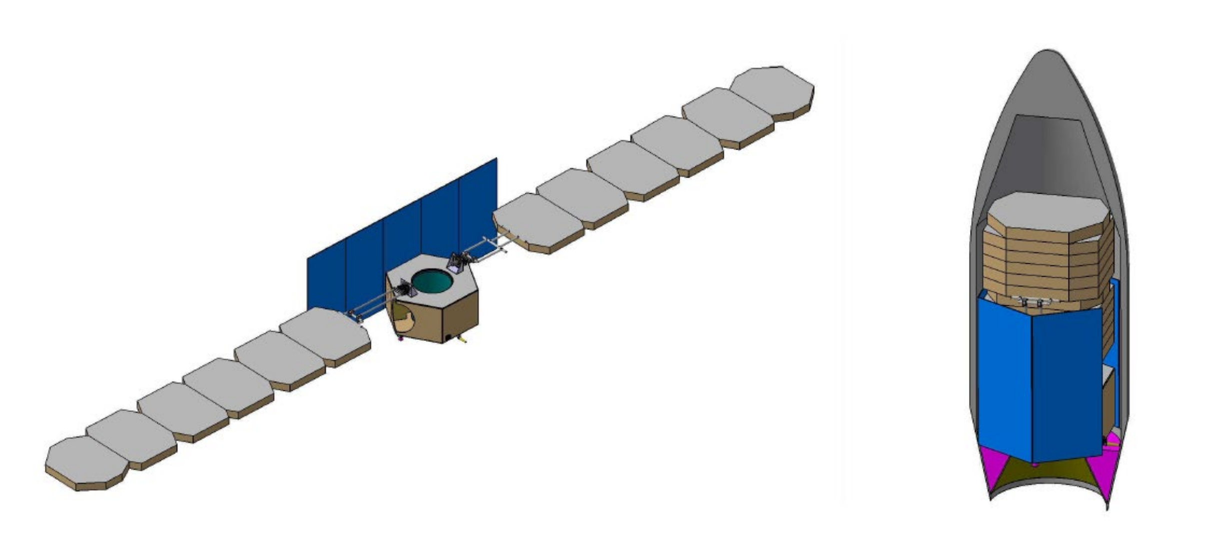
LOFT 2010

LOFT - a Large Observatory For x-ray Timing

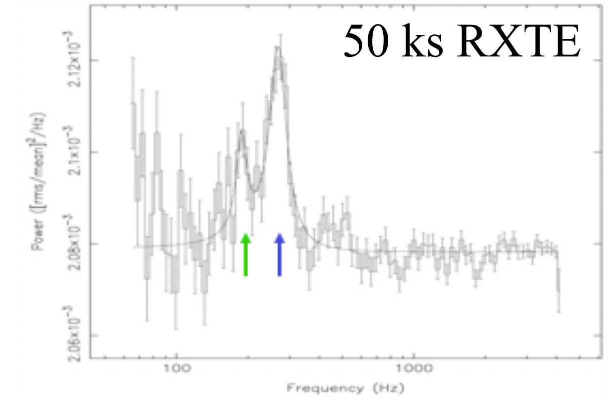
M. Feroci*[,a,b], L. Stella[c], A. Vacchi[d], C. Labanti[e], M. Rapisarda[f,a,b], P. Attinà[g], T. Belloni[h], R. Campana[a,b], S. Campana[h], E. Costa[a], E. Del Monte[a,b], I. Donnarumma[a], Y. Evangelista[a,b], G.L. Israel[c], F. Muleri[a], P. Porta[g], A. Rashevsky[d], G. Zampa[d], N. Zampa[d], G. Baldazzi[i], G. Bertuccio[j], V. Bonvicini[d], E. Bozzo[k], L. Burderi[l], A. Corongiu[m], S. Covino[h], S. Dall'Osso[c], D. De Martino[n], S. Di Cosimo[a], G. Di Persio[a], T. Di Salvo[o], F. Fuschino[e], M. Grassi[p], F. Lazzarotto[a], P. Malcovati[p], M. Marisaldi[e], M. Mastropietro[a], S. Mereghetti[q], E. Morelli[e], M. Orio[r], A. Pellizzoni[m], L. Pacciani[a,b], A. Papitto[l,m], L. Picolli[p], A. Possenti[m], A. Rubini[a,b], P. Soffitta[a], R. Turolla[s], L. Zampieri[t]

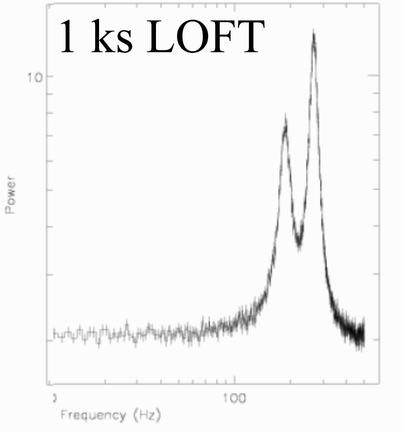
SPIE 2010 (San Diego)





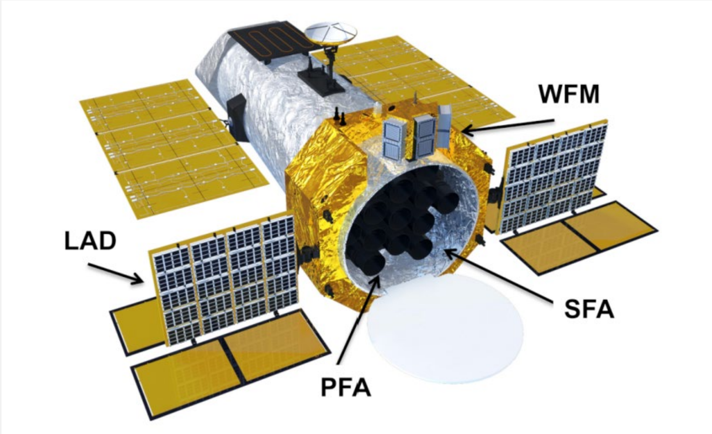
XTE J1550-564





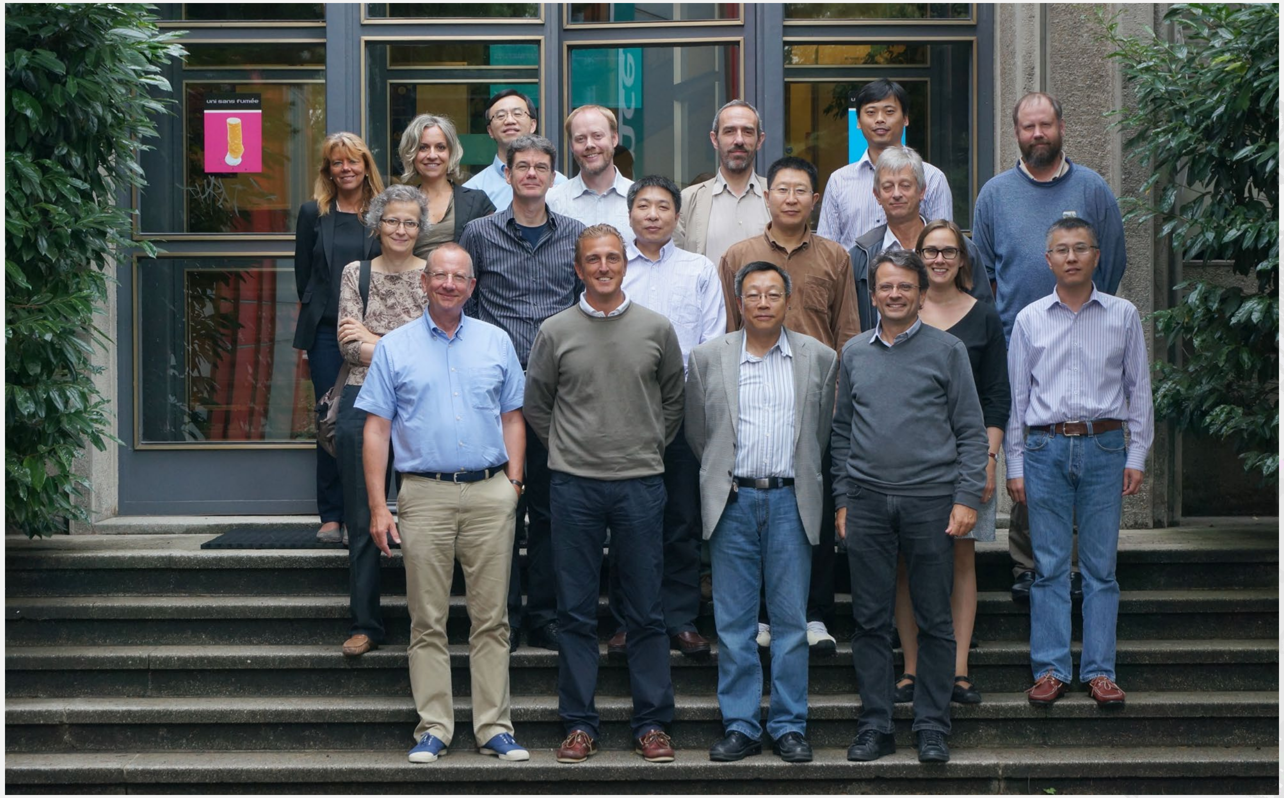
EXTP – ENHANCED X-RAY TIMING AND POLARIMETRY MISSION

2017



9 SFA (SDD) + 4 PFA
+ LAD + WFM
510 km ~0^{o}
LM7+Upper Stage

TOMASO AND EXTP

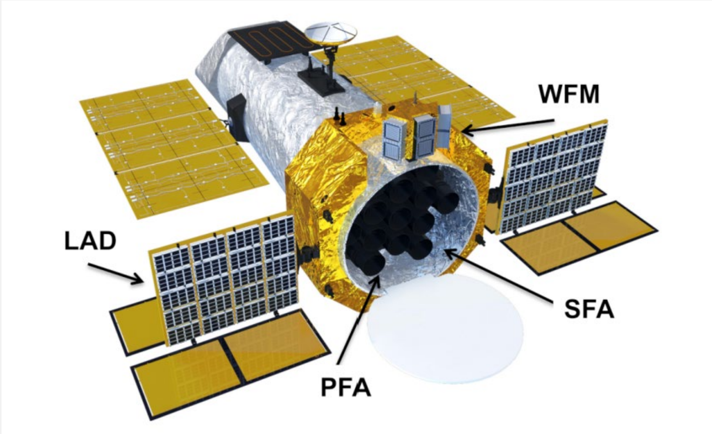


TOMASO AND EXTP

TOMASO IN BEIJING

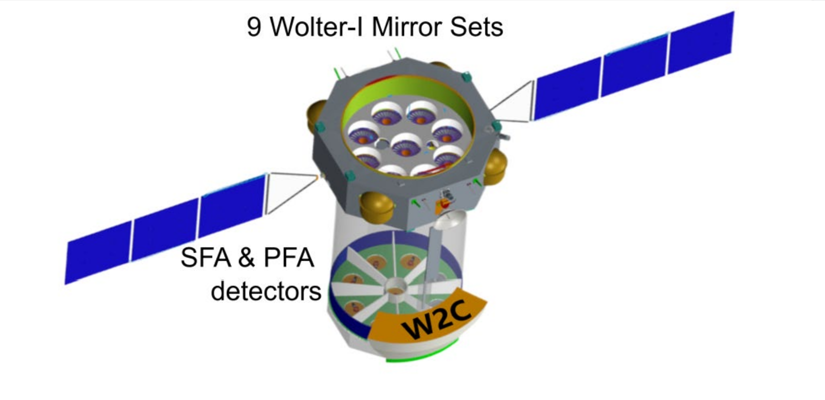
EXTP

2017



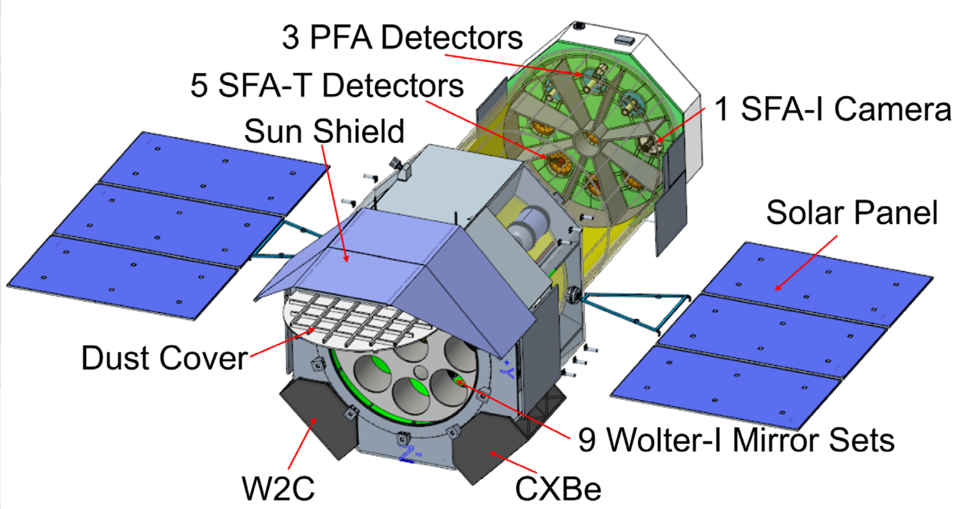
9 SFA (SDD)+4 PFA
+ LAD + WFM
510 km ~0º
LM7+Upper Stage

2025



6 SFA (5 SDD+ 1 PnCCD)
+3 PFA+W2C (~16 modules)
5000 km x100000 km
LM3B

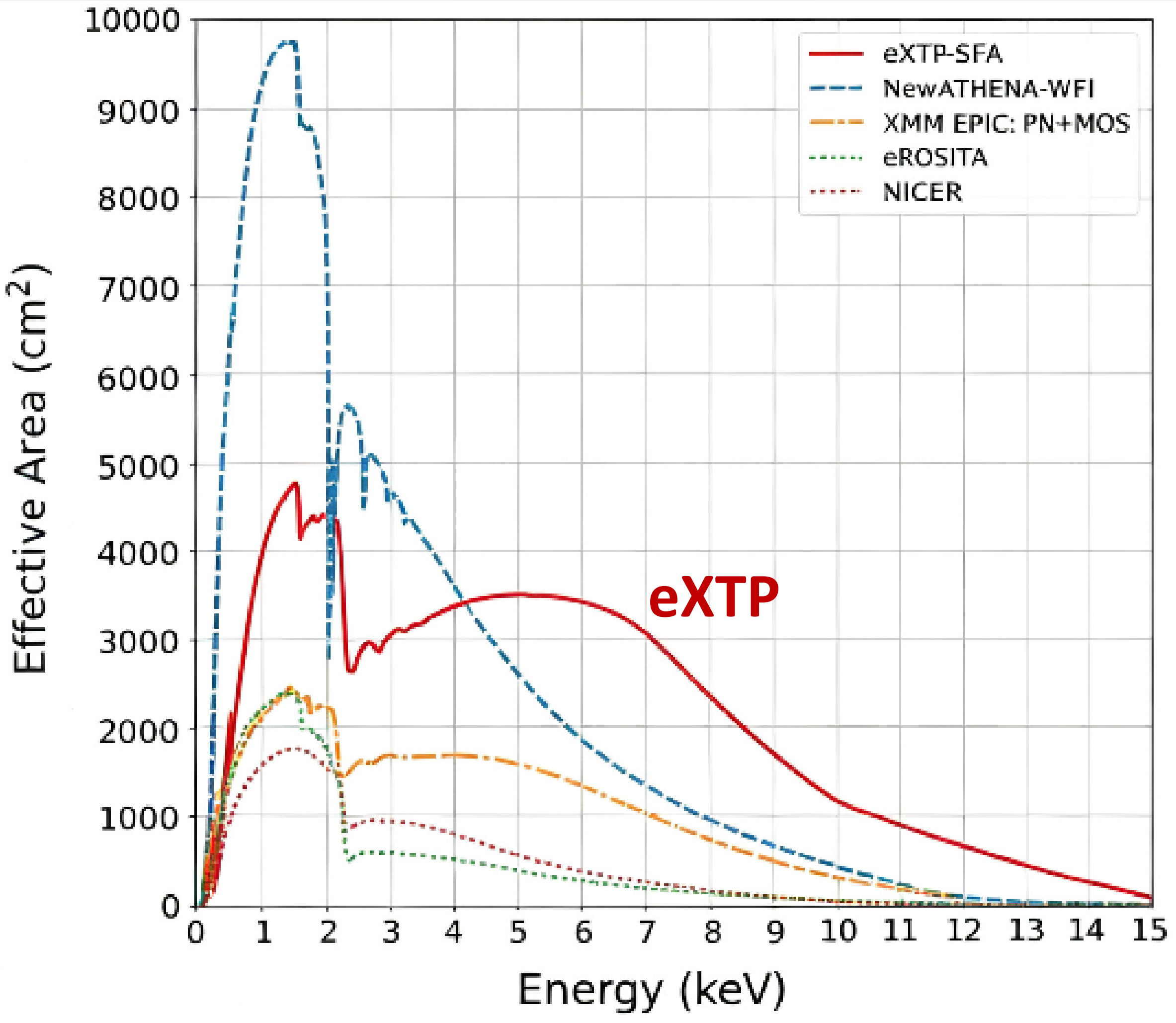
Current configuration

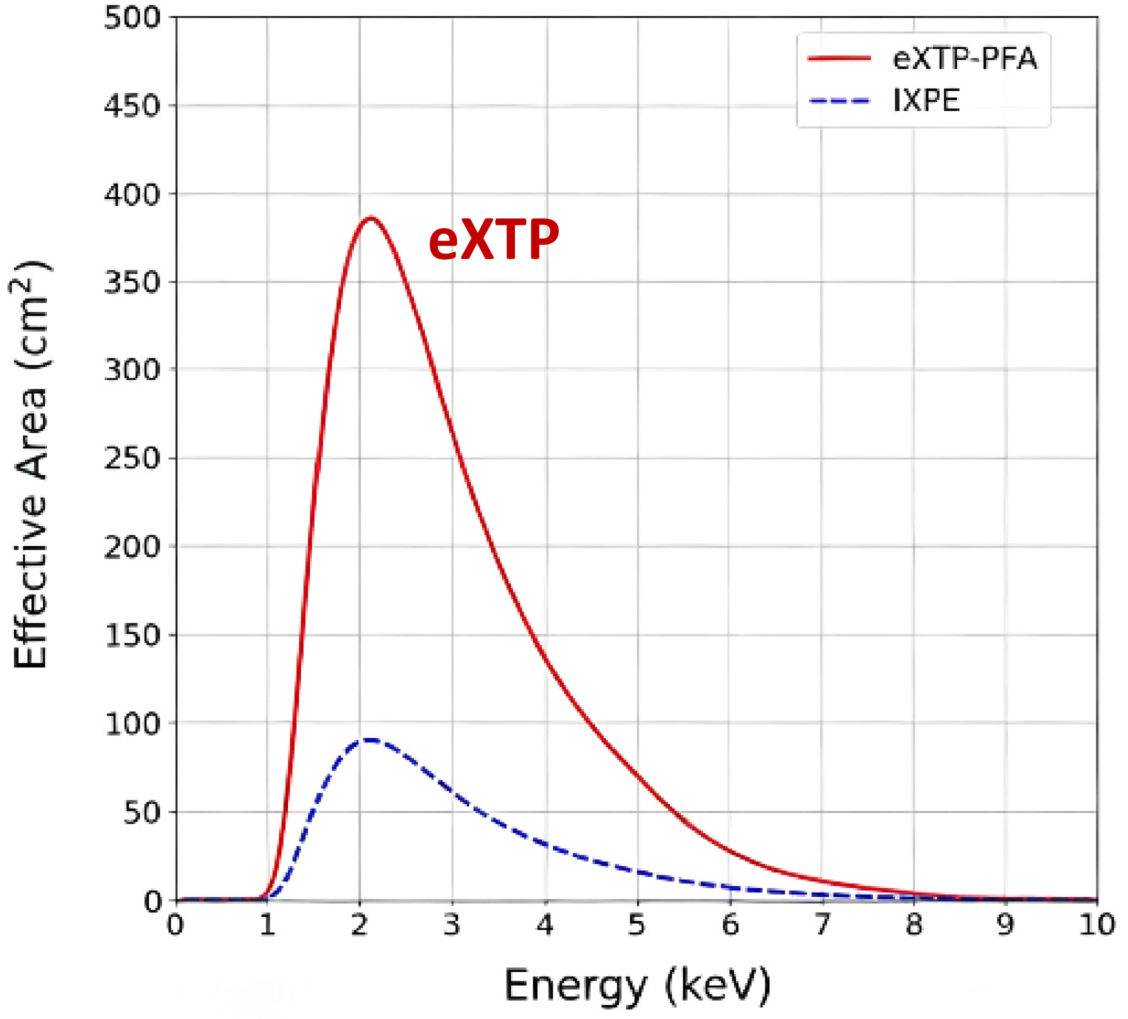


6 SFA (5 SDD+ 1 PnCCD)
+3 PFA+W2C (~88)+CXBe
610 km ~20º
LM8A

EXTP SFA AND PFA EFFECTIVE AREAS

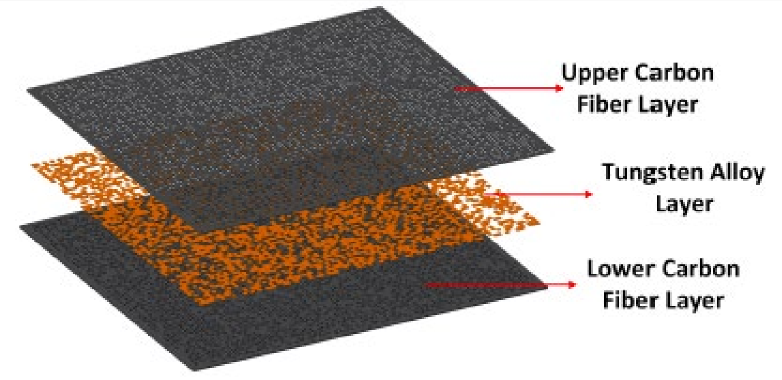
Marco Feroci
The many tones of accretion
Cefalù 2026



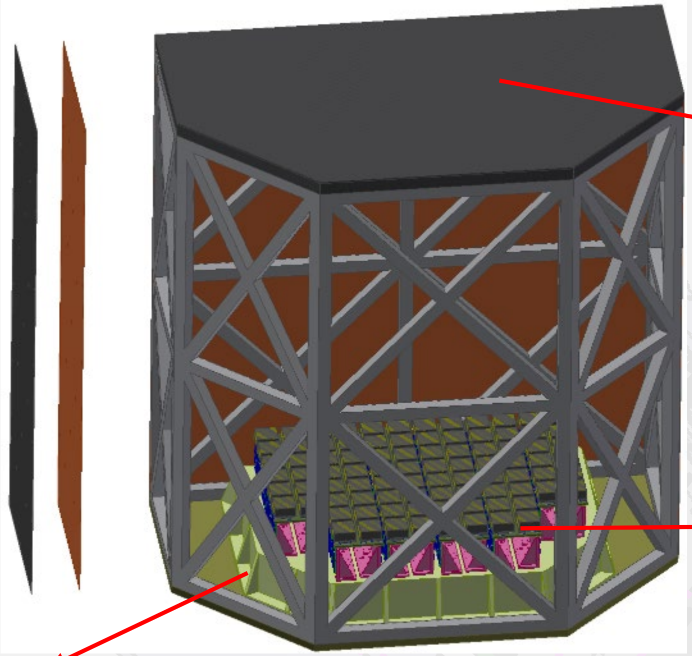


EXTP – WIDE BAND AND WIDE FIELD CAMERA

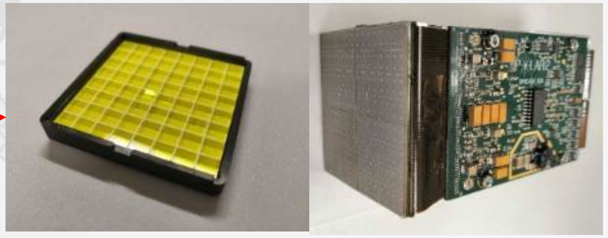
Coded-aperture mask



CFRP shell with tantalum **shielding**



BSD Detector Structure



8*8 **GAGG** + SiPM + FEE

W2C Composition: Coded Mask + Position-Sensitive Detector + BEE shared with CXBe
Detector Array: <u>48 detector units</u>, each with an 8*8 crystal array + SiPM + FEE
Energy Range: ~30 – 600 keV
Field of View: ~**528 deg^2** (fully coded), ~**1804 deg^2** (half coded) for 48 DUs
Position accuracy: < 5′

EXTP – UPDATED WHITE PAPERS (2025)

- White papers on
  - Dense matter
  - Strong gravity
  - Strong magnetism
  - Time-domain and multi-messenger
  - Observatory science

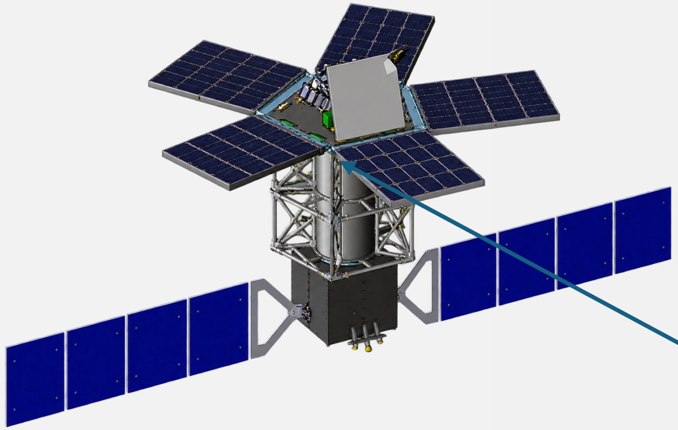
The enhanced X-ray Timing and Polarimetry mission—eXTP for launch in 2030 Zhang, S. N., Santangelo, A., Xu, Y. et al. 2025, SCPMA, 68, 119502
Dense matter in neutron stars with eXTP Li, A., Watts, A. L., Zhang, G. et al. 2025, SCPMA, 68, 119503
Probing the strong gravity region of black holes with eXTP Bu, Q., Bambi, C., Gou, L. et al. 2025, SCPMA, 68, 119504
Physics of strong magnetism with eXTP Ge, M., Ji, L., Taverna, R. et al. 2025, SCPMA, 68, 119505
Prospects for time-domain and multi-messenger science with eXTP Yi, S.-X., Zhao, W., Xu R.-X. et al. 2025, SCPMA, 68, 119506
Observatory science with eXTP Zhou, P., Mao, J., Zhang, L. et al. 2025, SCPMA, 68, 119507

EXTP – INTERNATIONAL SCIENCE WORKING GROUPS

China General Coordinator: Mingyu Ge, Ping Zhou coordinators		Europe General Coordinator: Andrea Santangelo, Silvia Zane coordinators
Ang Li, Guobao Zhang, Wenfei Yu	WG1: Dense Matter	Anna Watts， Sebastien Guillot
Lijun Gou, Qingcui Bu, Cosimo Bambi	WG2: Extreme Gravity	Alessandra De Rosa, Phil Uttley
Mingyu Ge, Long Ji	WG3: Strong Magnetism	Roberto Taverna, Sergey Tsygankov
Xuefeng Wu, Renxin Xu， Shuxu Yi， Wen Zhao	WG4: TDMMA	Giulia Stratta, Simone Dall’Osso Roland Walter
Ping Zhou , Liang Zhang, Jirong Mao	WG5: Observatory Science	Enrico Bozzo , Alessandro Patruno

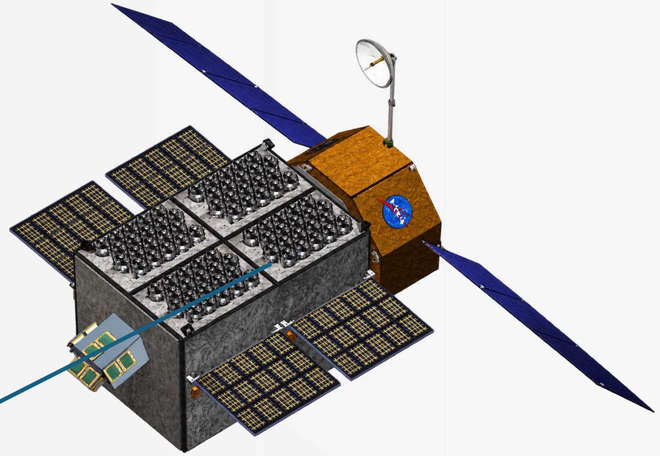
FROM THE HERITAGE OF LOFT AND EXTP…

Marco Feroci
The many tones of accretion
Cefalù 2026

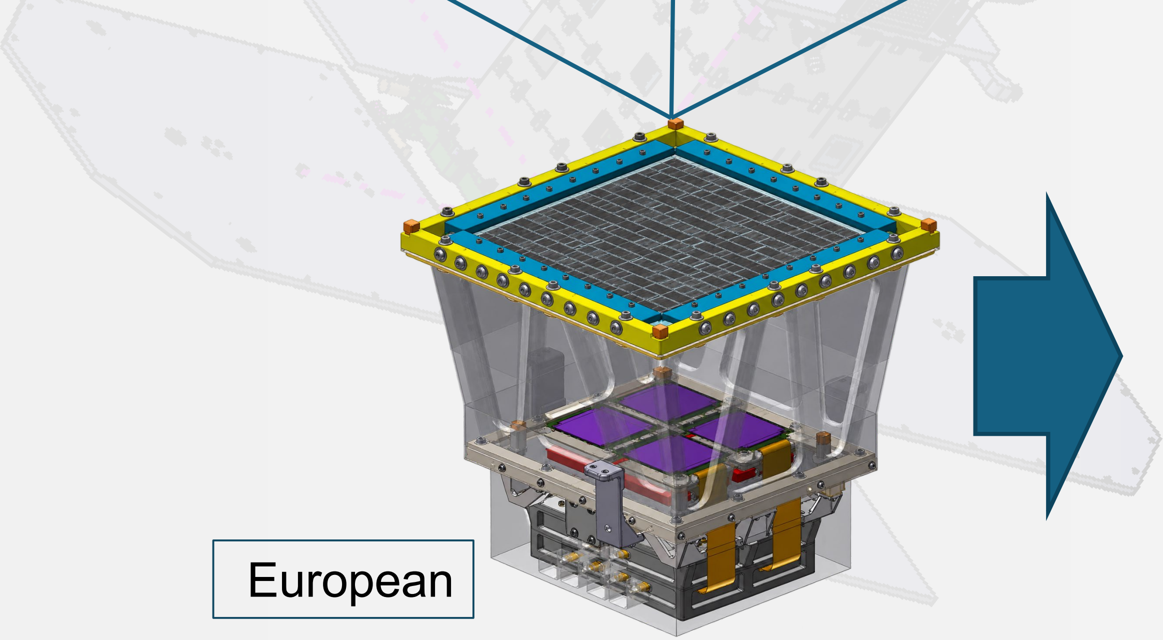


LOFT

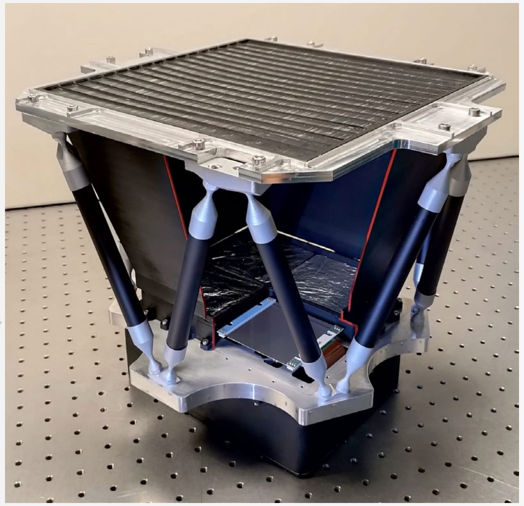
eXTP



STROBE-X

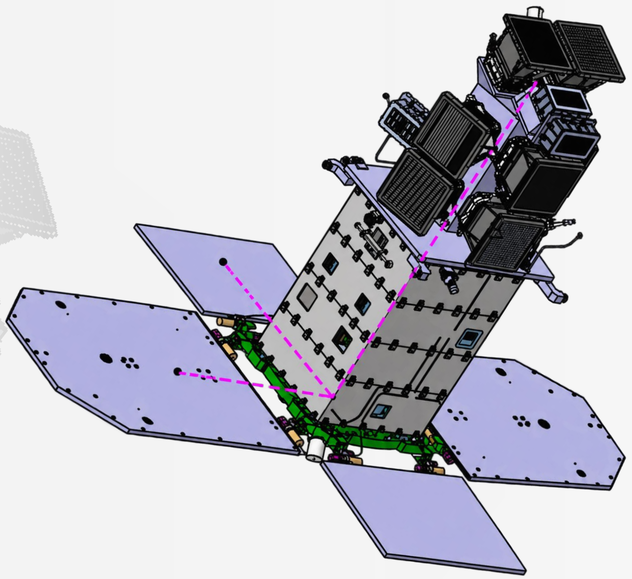


European



National

…TO GECO AND LEM-X

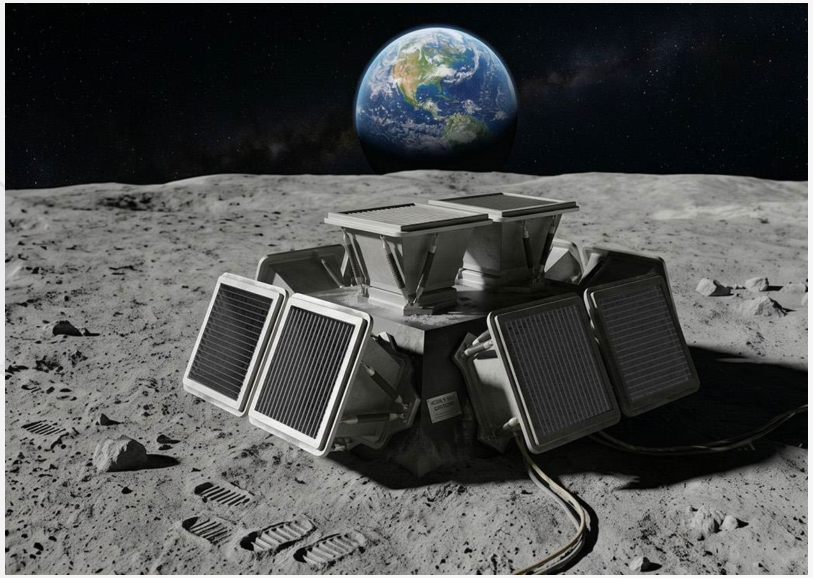


- **GECO**

Galactic and Extragalactic Compact-objects Observatory

- **LEM-X**

Lunar Electromagnetic Monitor in X-rays



GECO – PROGRAMMATIC CONTEXT

Mission proposal in response to a Call for Small Missions, jointly issued by ASI and INAF in February 2026 for the Italian community.

Boundary conditions of the Call:

- Fast-track mission: 5 years from selection to launch
- Payload mass: <100 kg
- Maturity of the technology: TRL≥5 at the proposal
- Cost cap A-E1 <60 M€ (excluding launch and ground services)
- Orbit: LEO

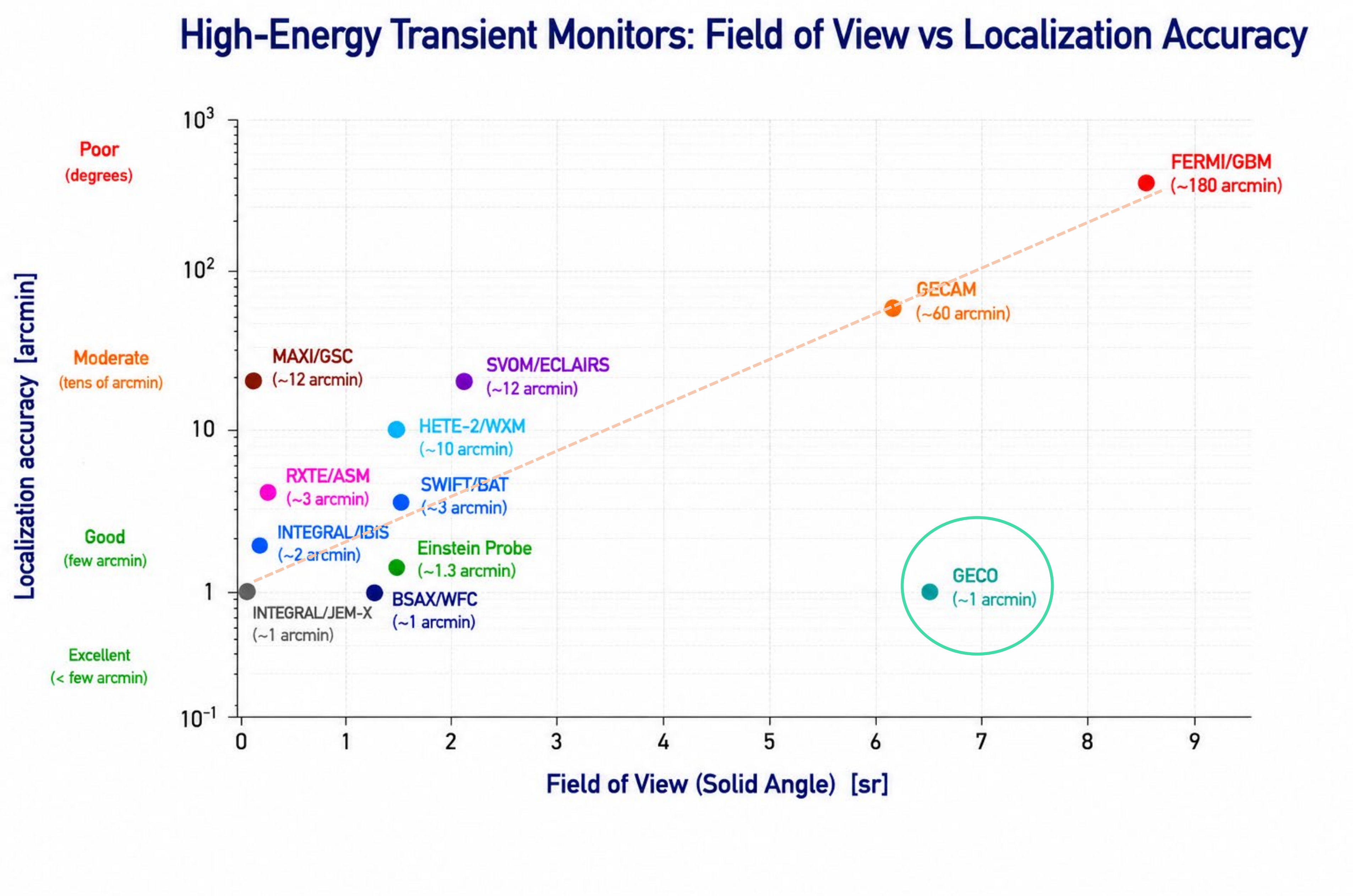
- 3 candidates selected for a 18-month Phase A/B1 study
- 2 candidates down-selected for a 12-month Phase B2 study
- 1 candidate down-selected for implementation

GECO – CONCEPT

- Two broad science pillars:
  - Time Domain Astronomy
  - Multi-messenger Astrophysics
- The GECO motto: "*everywhere, all the time*".
- Combine for the first time on a single satellite:
  - Sky coverage: 50% of the sky at any time
  - X-ray imaging: 5-arcmin angular resolution, 1-arcmin PSLA
  - X to gamma-ray spectral coverage: 2 keV – 2 MeV
  - X-ray spectral resolution: 350 eV FWHM @6 keV
  - Photon-by-photon data and fast-alert
- Build on existing and mature technology.

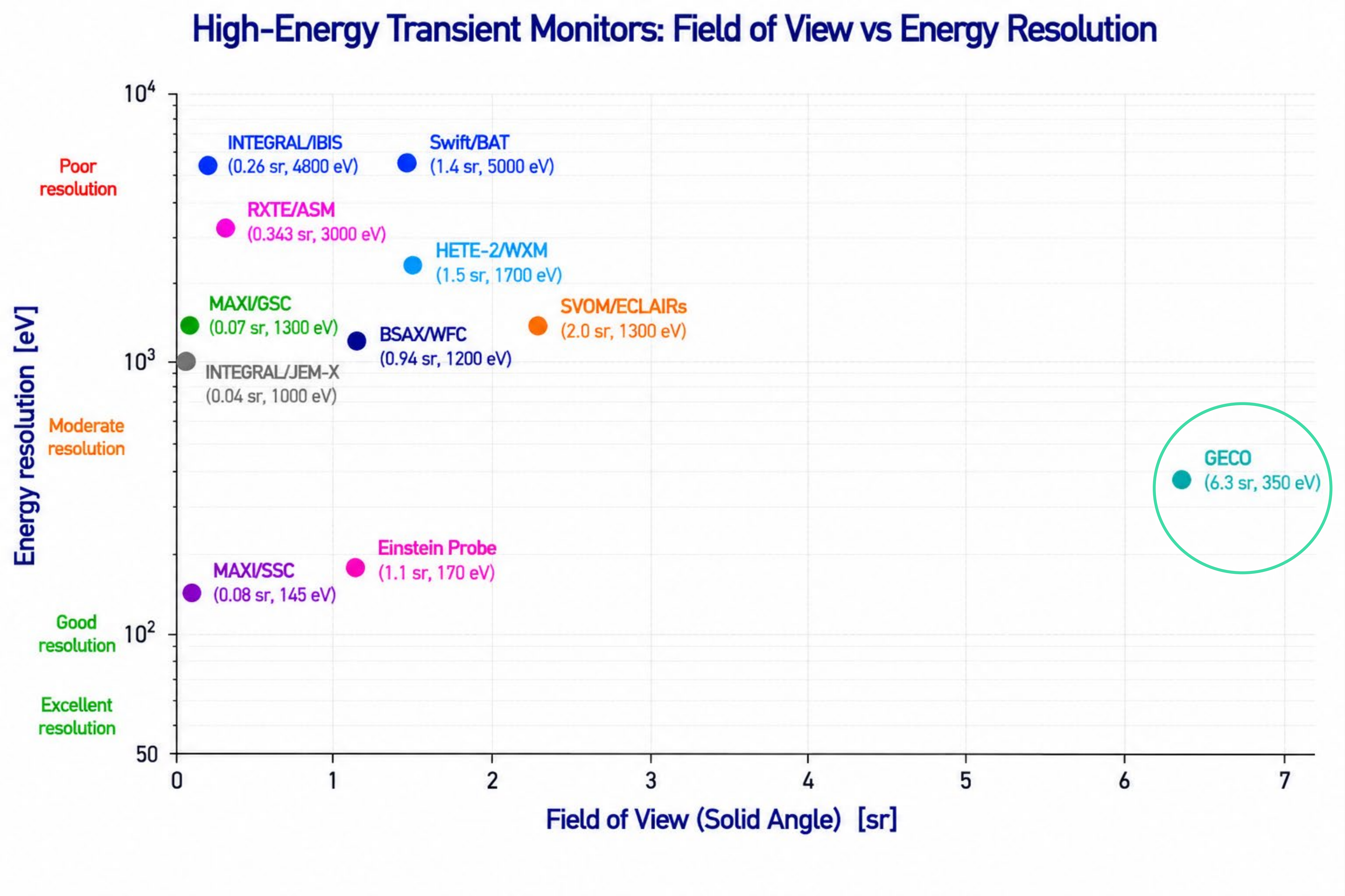
GECO
GALACTIC AND EXTRAGALACTIC COMPACT-OBJECT OBSERVATORY

GECO IN THE PAST AND PRESENT SCENARIO - 1



GECO
GALACTIC AND EXTRAGALACTIC COMPACT-OBJECT OBSERVATORY

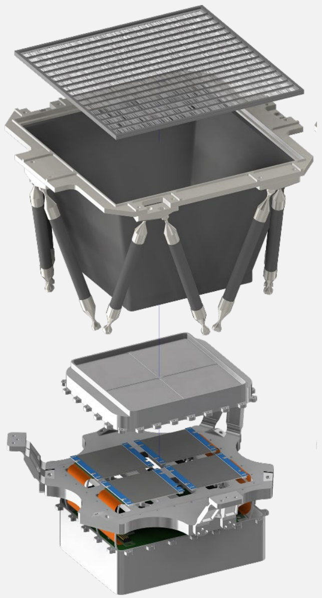
GECO IN THE PAST AND PRESENT SCENARIO - 2

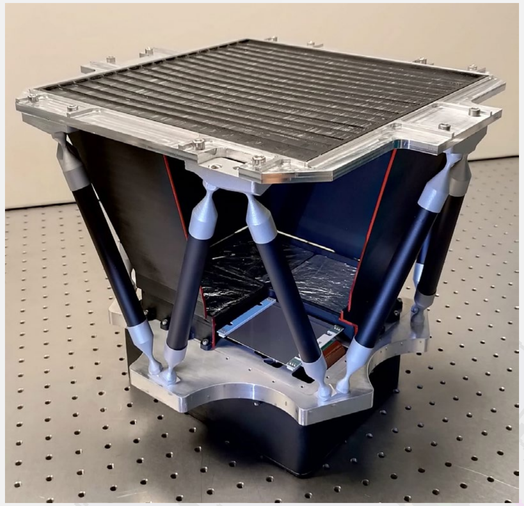


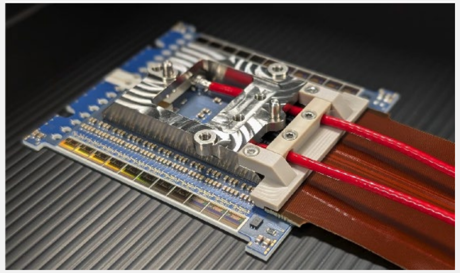
GECO – PAYLOAD

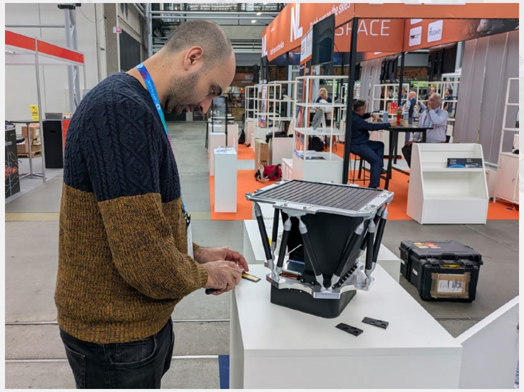
INAF

ASM – All Sky Monitor

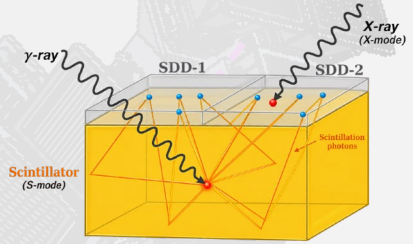


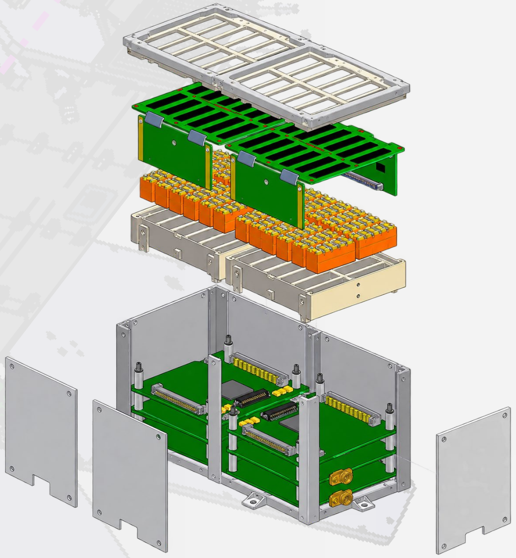






BURST – Broadband Universal Radiation Spectrometer for Transients

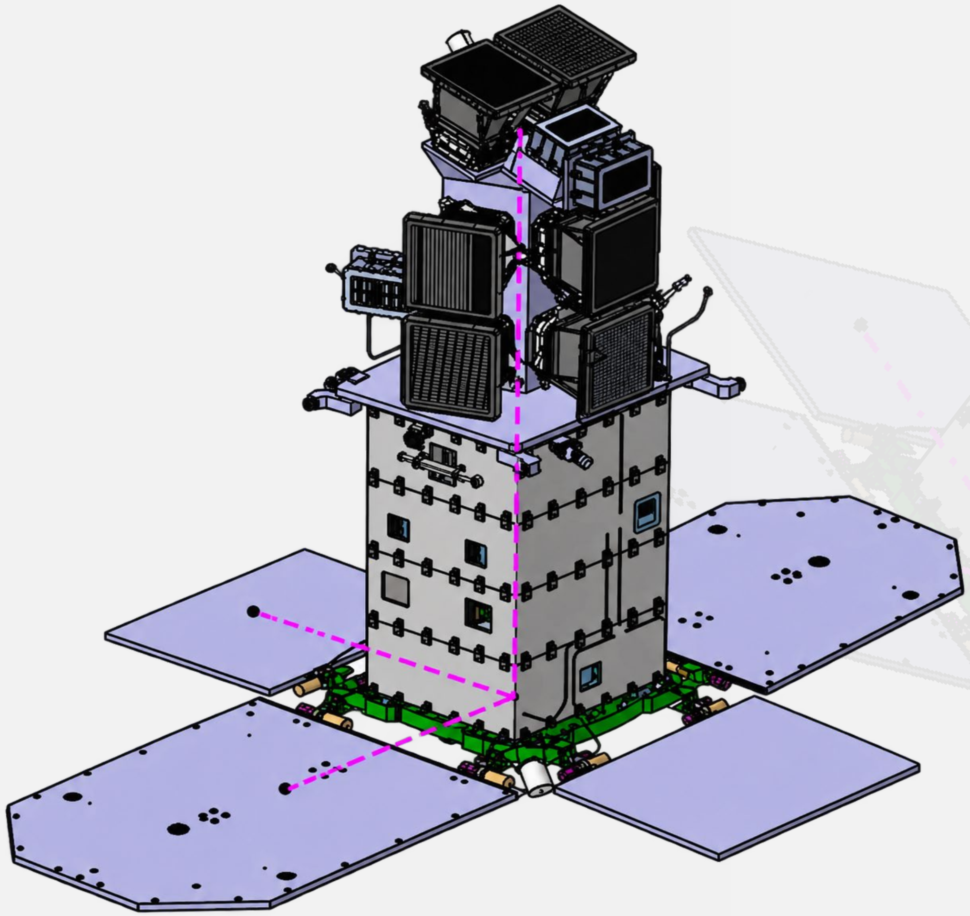




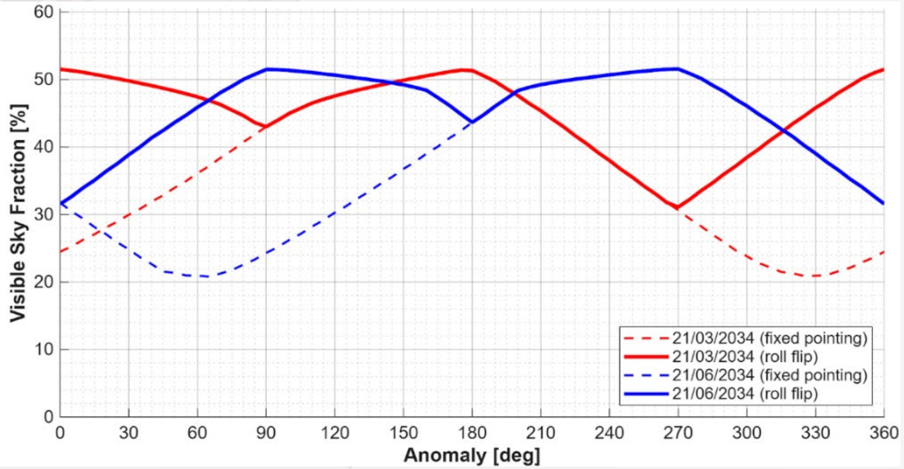
GECO – PAYLOAD SPECIFICATIONS

Instrument	ASM	BURST
Total FoV	2π (50% of the sky)	2π (50% of the sky)
Peak effective area per element	70 cm^2	100 cm^2
No. of elements	4×2	4
Energy range	2–50 keV	5 keV – 2 MeV
Energy resolution	350 eV @ 6 keV	<500 eV @6 keV (X-mode) ~5% @ 662 keV (S-mode)
Time resolution	10 μs	1 μs
Angular resolution and Point Source Location Accuracy (PSLA)	4.5´ angular resolution <1´ PSLA	N/A
Sensitivity	Better than 1500 mCrab (1s, 5σ) and better than 6.5 mCrab (50 ks, 5σ) on **50%** of the sky Better than 1000 mCrab (1s, 5σ) and better than 4.5 mCrab (50 ks, 5σ) on **33%** of the sky	Long GRBs, in 1 s: <0.6 ph cm^{-2} s^{-1} (50–300 keV) Short GRBs, in 64 ms: <4 ph cm^{-2} s^{-1} (50–300 keV)

GECO – MISSION

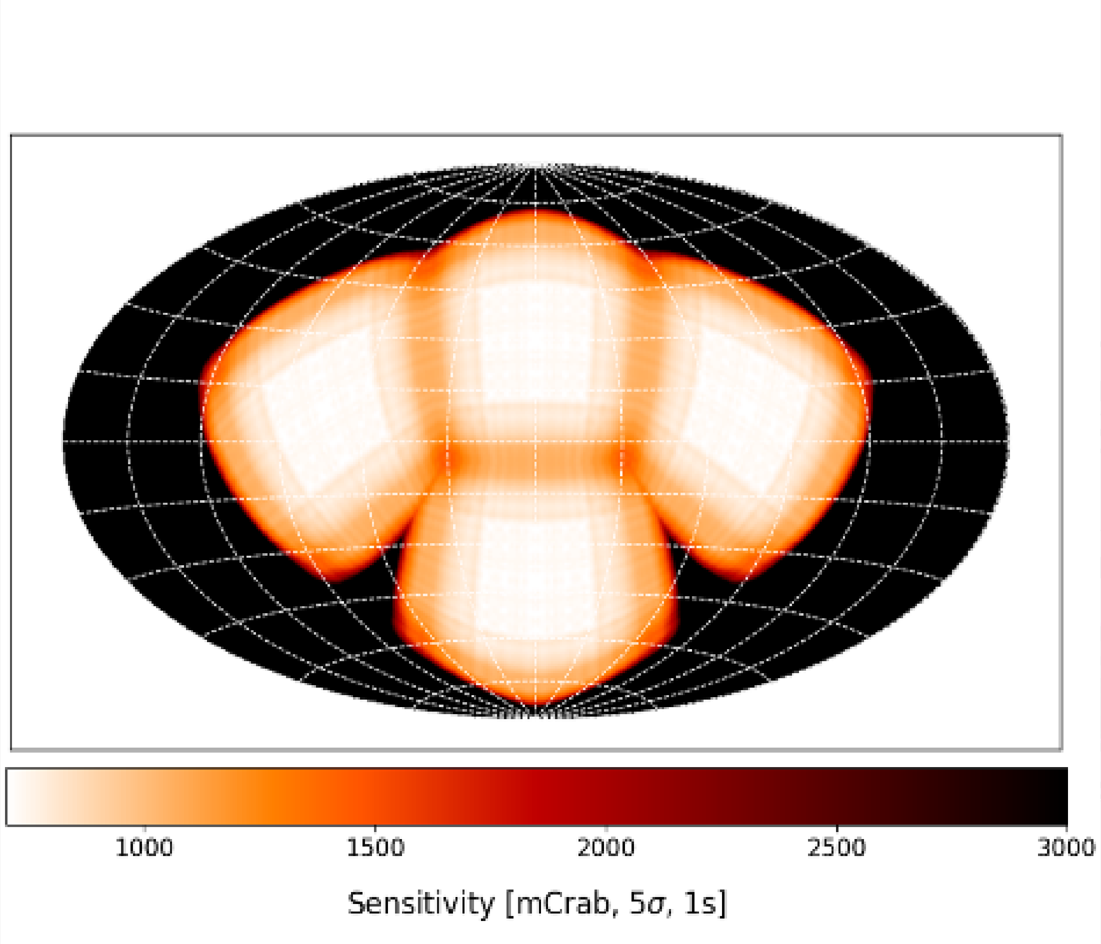


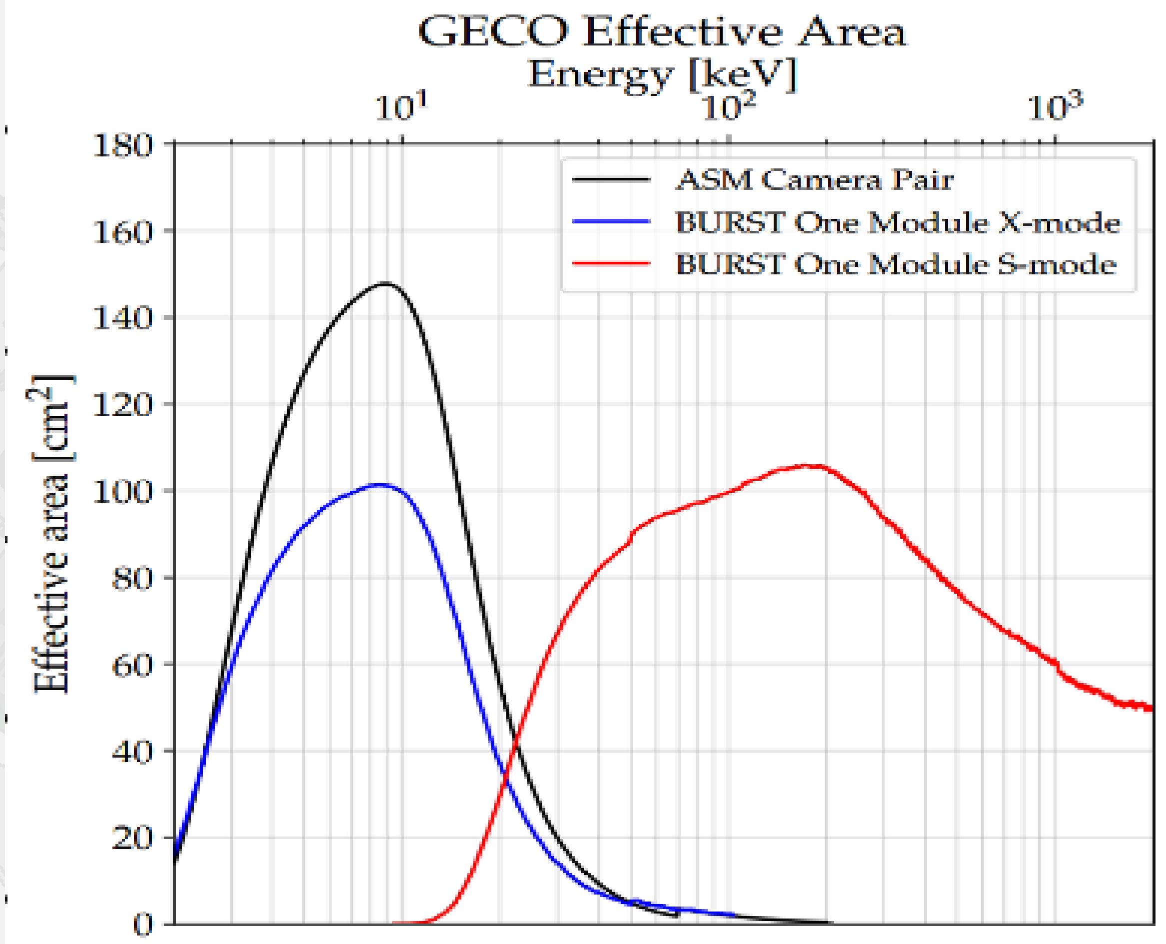
Requirement	Value
Lifetime	3+2 years
Orbit	LEO <3°, ≤500 km
Availability	~85% of orbit
APE/AKE (3σ)	0.5 arcmin
ASM/BURST Module unobstructed FoV	90°×90° (each Module)
Timing	PPS 1 μs 3σ, 10 MHz
Rapid Alert Dissemination	< 60 s



GECO
GALACTIC AND EXTRAGALACTIC
COMPACT-OBJECT OBSERVATORY

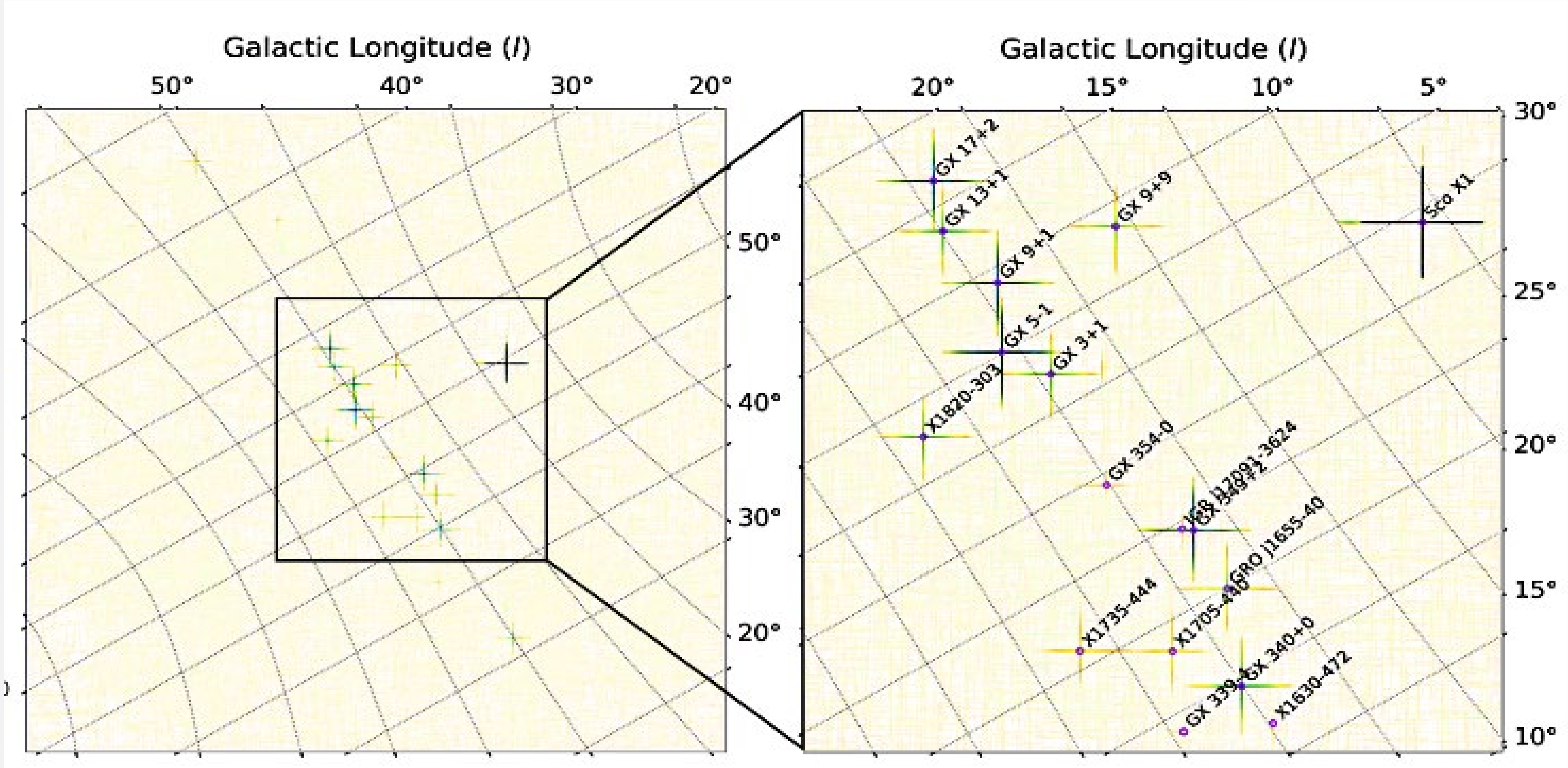
GECO – ANTICIPATED PERFORMANCE





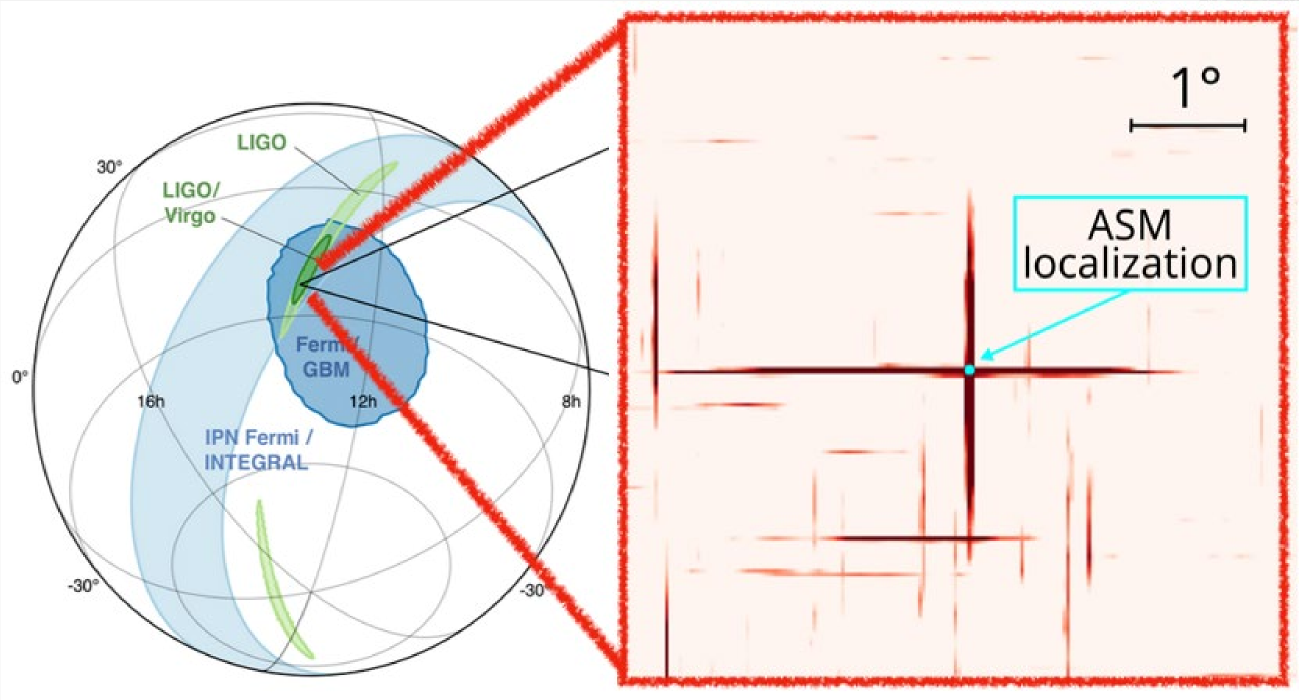
GECO – ALL SKY MONITORING

Simulated 1-ks GC observation of one GECO/ASM unit

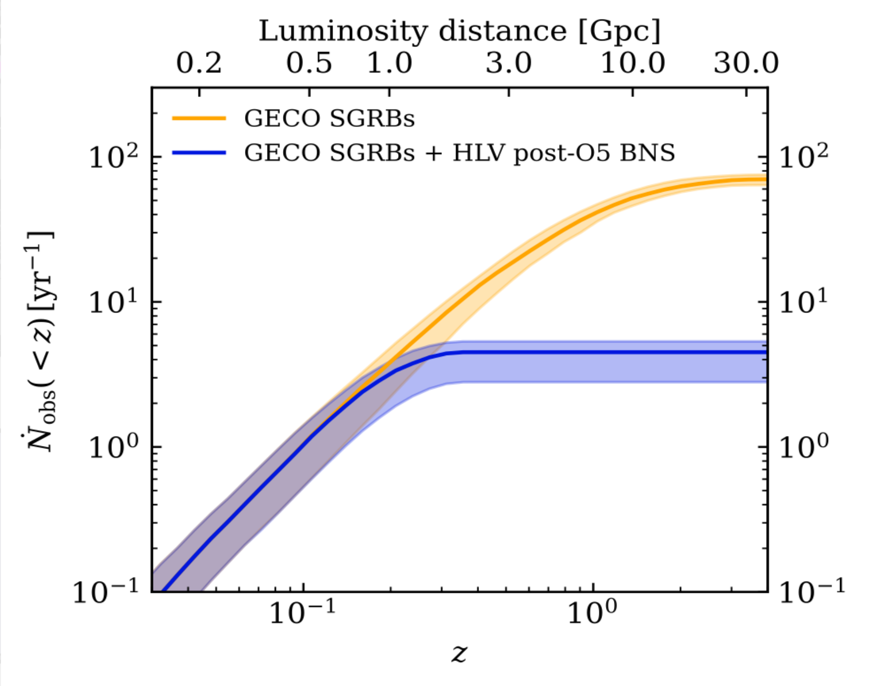


GECO IN THE MULTI-MESSENGER CONTEXT

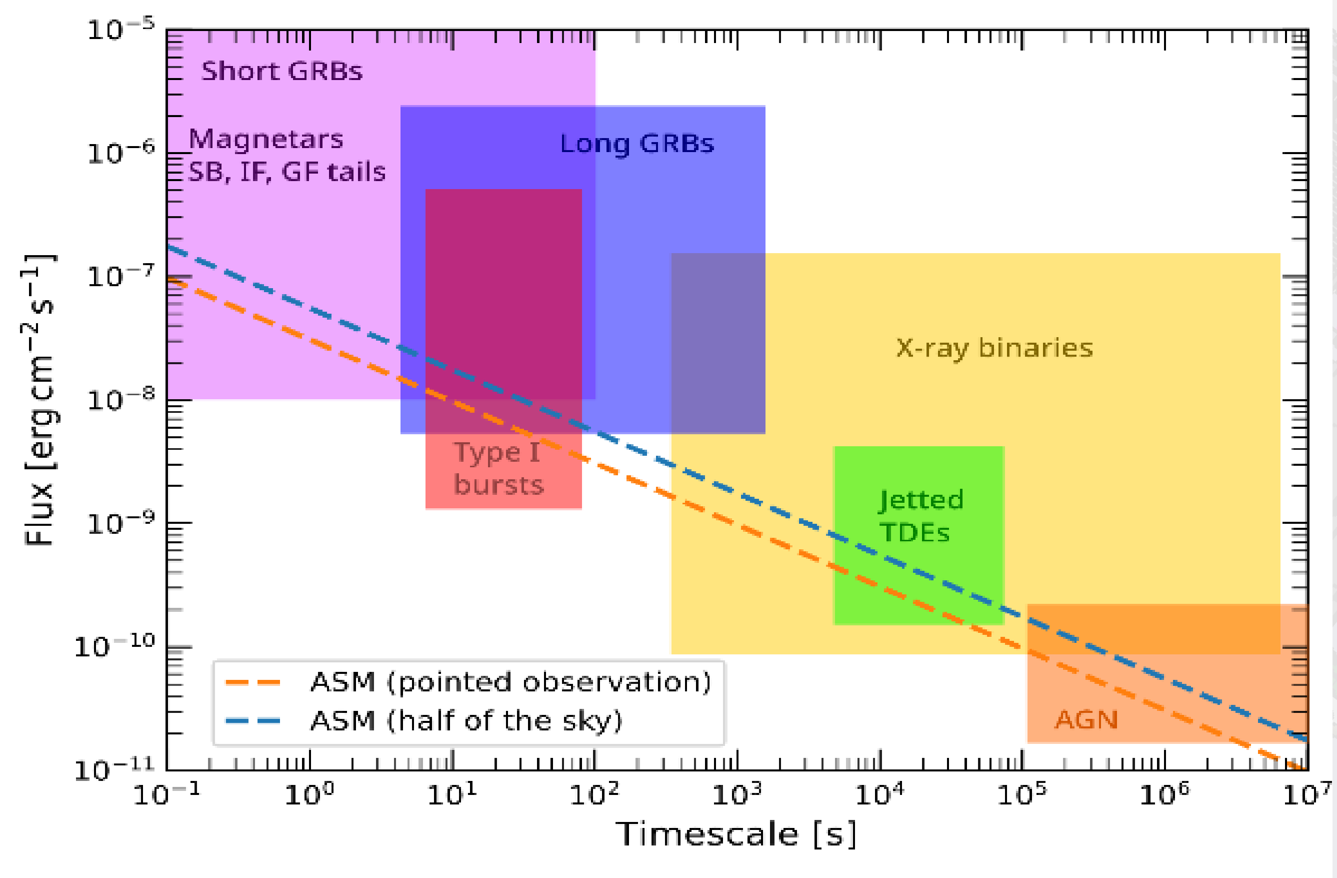
Simulated GECO/ASM observation of GW170817



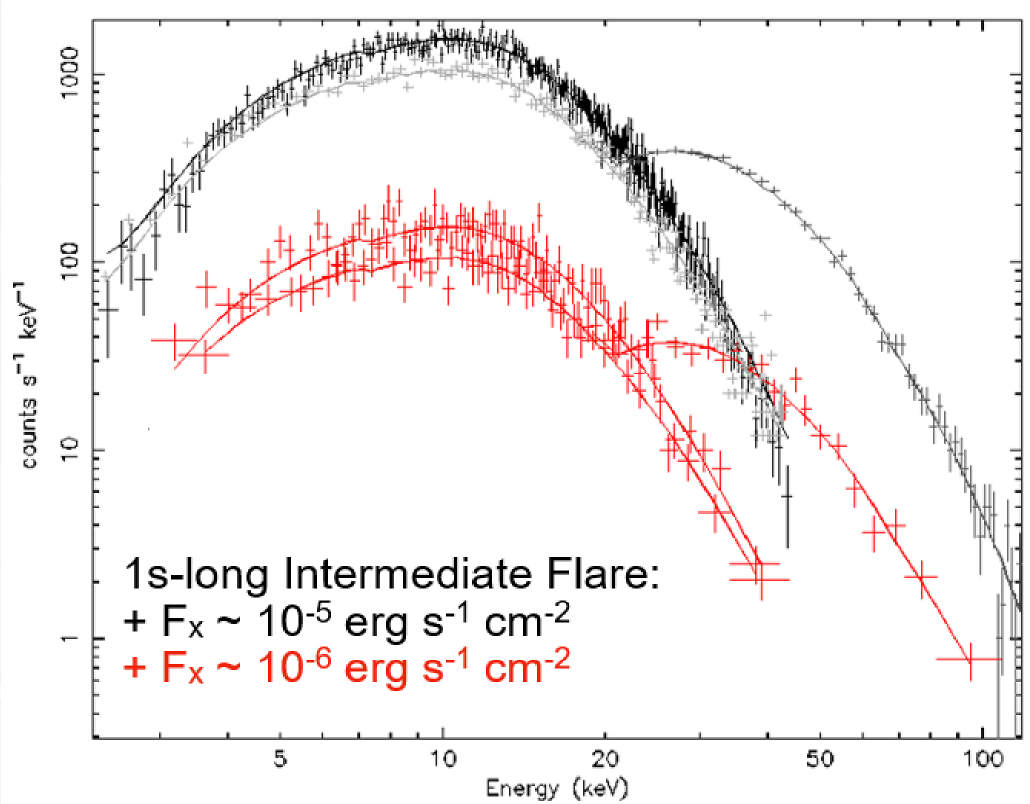
GECO/BURST short GRBs vs z



GECO AND TIME DOMAIN ASTRONOMY



Case Study: magnetar intermediate flare



CHANGING VIEWPOINT: LEM-X

LEM-X – WHY ON THE MOON??

- Everybody is going… why don't we??

- Advantages:
  - Stable environment for continuous observations
  - Wide site, enabling (modular) deployment of instruments larger than free flyers
  - Full-sky access with lunar rotation (or with double site)
  - Synergy with other Moon-based observatories
  - Future Moon base and serviceability?

- Disadvantages:
  - Dust
  - Temperature: absolute value and day/night variations
  - Meteoroids
  - High transport costs

LEM-X - PERSPECTIVES

- Deployment of a *pathfinder* (a single LEM-X Camera/Unit) on the Moon's surface for feasibility demonstration purposes (likely South Pole and one lunar day operation only)

- Full LEM-X implementation requires:
  - Transportation at reasonable cost
  - Local power source to survive the lunar night
  - Local infrastructure for communication

CONCLUSIONS

The observational capabilities in X-rays in the next decade will likely be very much reduced when compared to the past and current decade, especially for the Galactic science.

The Chinese eXTP mission will likely be the most important high-sensitivity mission in the decade, bridging the community to NewATHENA in the 40's.

New national and/or multi-lateral initiatives and community pressure on decision makers are a strong, nearly vital need for the X-ray community.