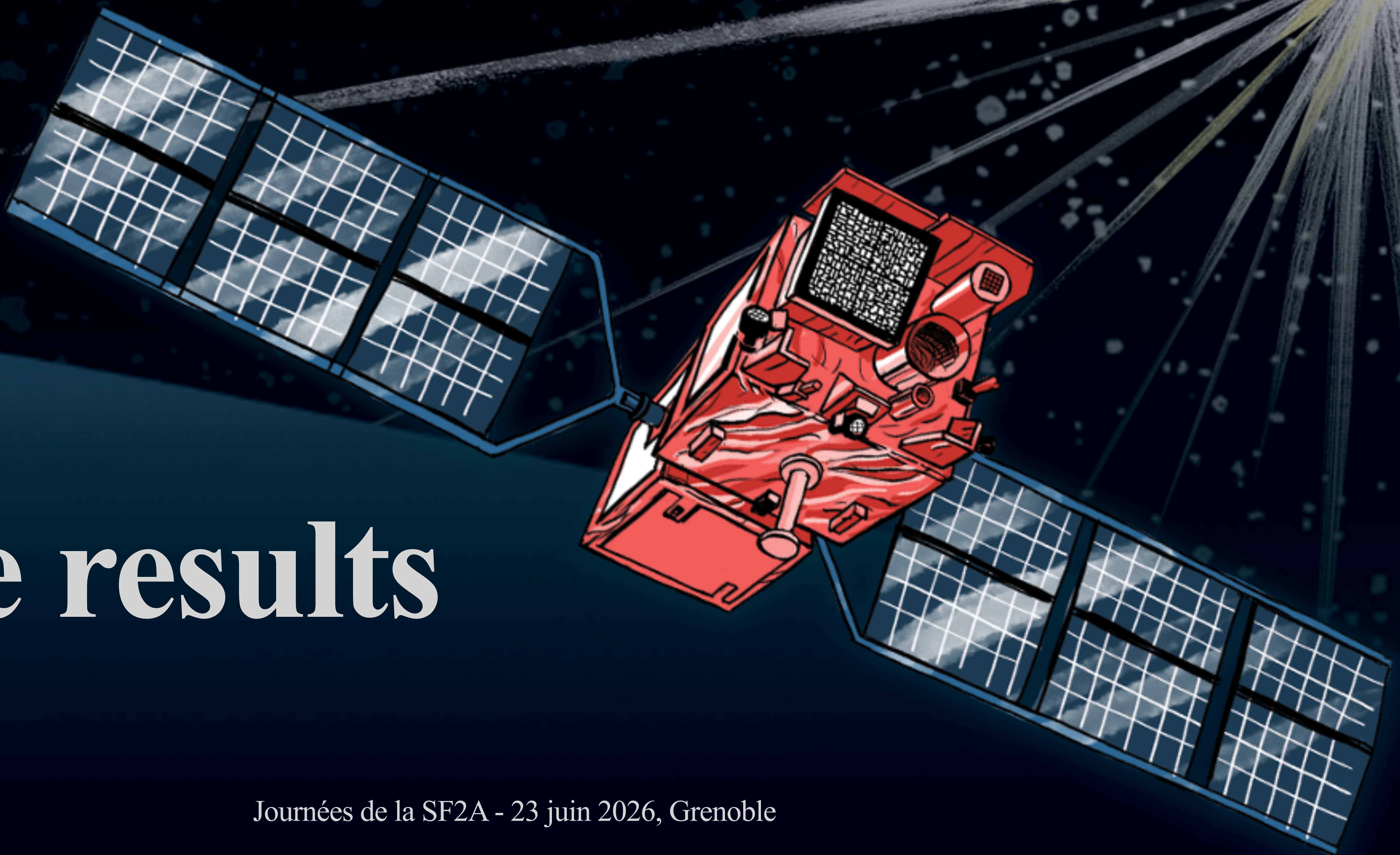
Jesse T. Palmerio (CEA/AIM)

on behalf of Bertrand Cordier
for the SVOM collaboration

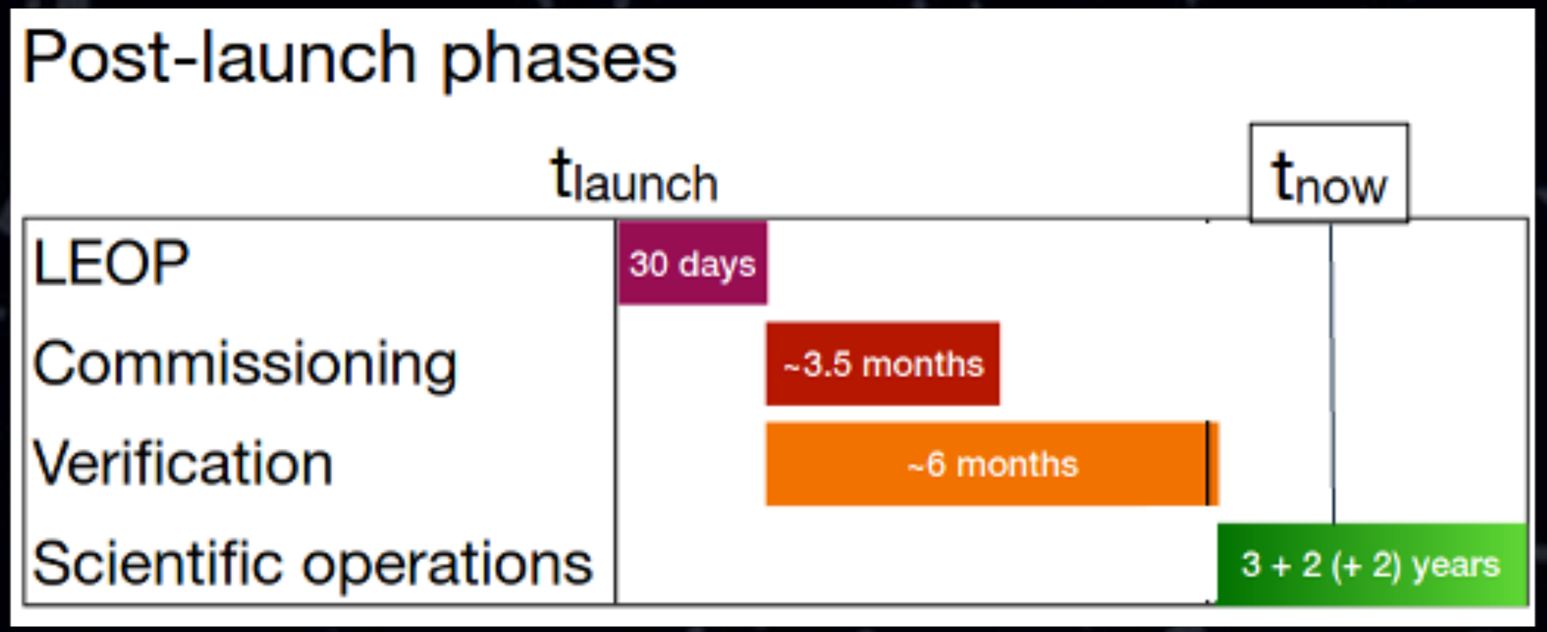


First science results

Journées de la SF2A - 23 juin 2026, Grenoble

Space -based multi-band astronomical Variable Object Monitor

- June 22 2024: Launch from Xichang (Sichuan) by a LM-2C rocket
- January 2025: Beginning of scientific exploitation (nominal phase)
- Lifetime: 3+2 years (+ extension)



The SVOM consortium

- **China (P.I. J. Wei)**
  SECM Shangai
  Beijing Normal University
  Central China University Wuhan
  Guangxi University Nanning
  IHEP Beijing
  KIAA Peking University
  Nanjing University
  NAOC Beijing
  National Astronomical Observatories
  Purple Mountain Observatory Nanjing
  Shangai Astronomical Observatory
  Tsinghua University Beijing
- **Mexico, UNAM (Colibri)**
- **France (PI B. Cordier)**
  CNES Toulouse
  APC Paris
  CEA Saclay
  CPPM Marseille
  Obs. de Paris - LUX
  IAP Paris
  IJCLab Orsay
  IRAP Toulouse
  LAM Marseille
  LUPM Montpellier
  ObAS Strasbourg
- **UK, University of Leceister (MXT)**
- **Germany, MPE Garching & IAAT Tübingen (MXT)**

https://fsc.svom.org/home/collaboration/collaborators

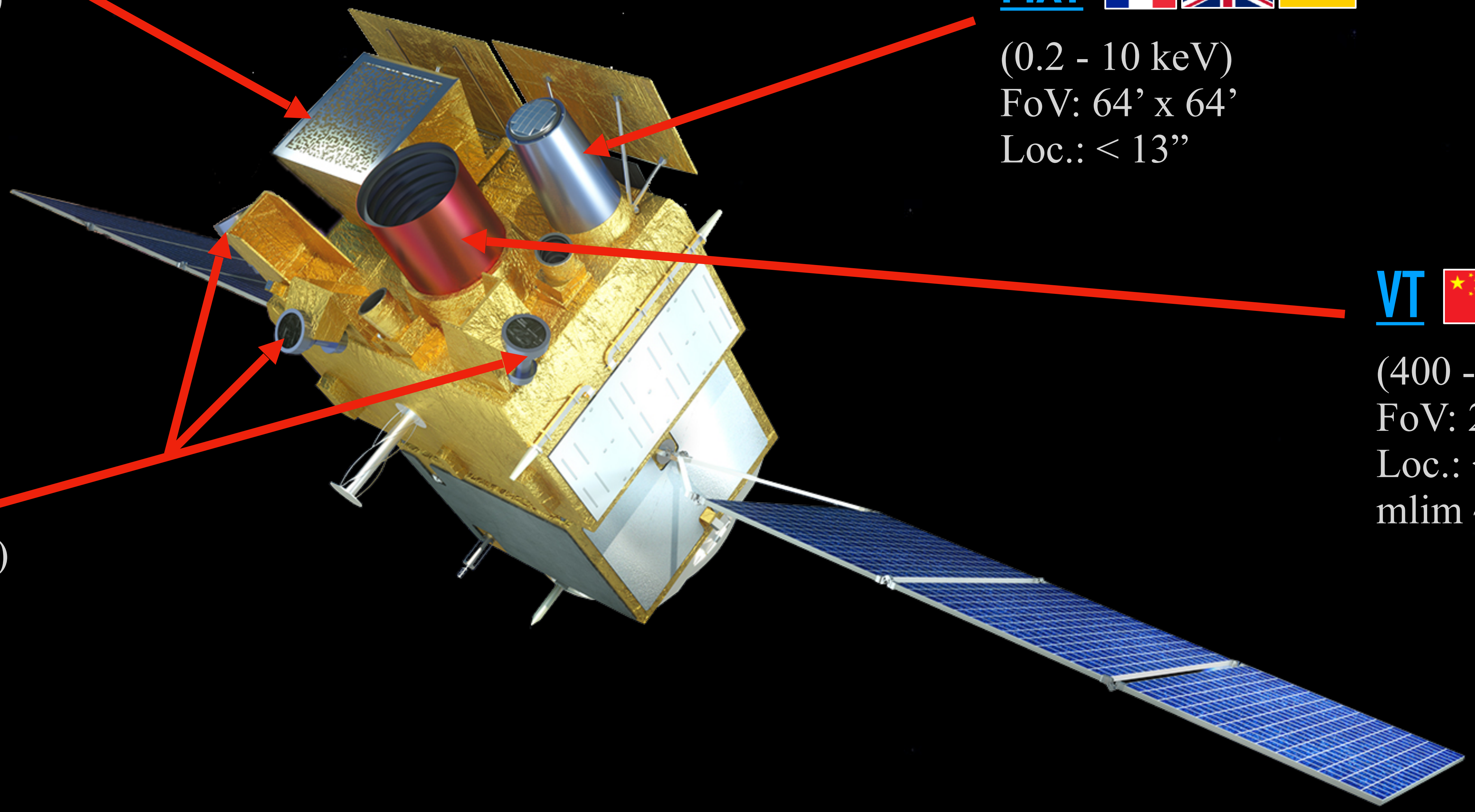
https://www.svom.eu

Space Variable Object Monitor

SPACE

ECLAIRS
(4 - 150 keV)
FoV: ~ 2 sr
Loc.: < 12’

MXT
(0.2 - 10 keV)
FoV: 64’ x 64’
Loc.: < 13”



VT
(400 - 1000 nm)
FoV: 26’ x 26’
Loc.: < 1”
mlim ~ 22.5 (V - 300 s)

GRM
(30 keV - 5 MeV)
FoV: ~ 5.6 sr
Loc.: 5 - 10°

GROUND

GWAC
(500 - 800 nm)
FoV: 2x5000 deg2
40 cameras
mlim ~ 16 (V - 10 s)

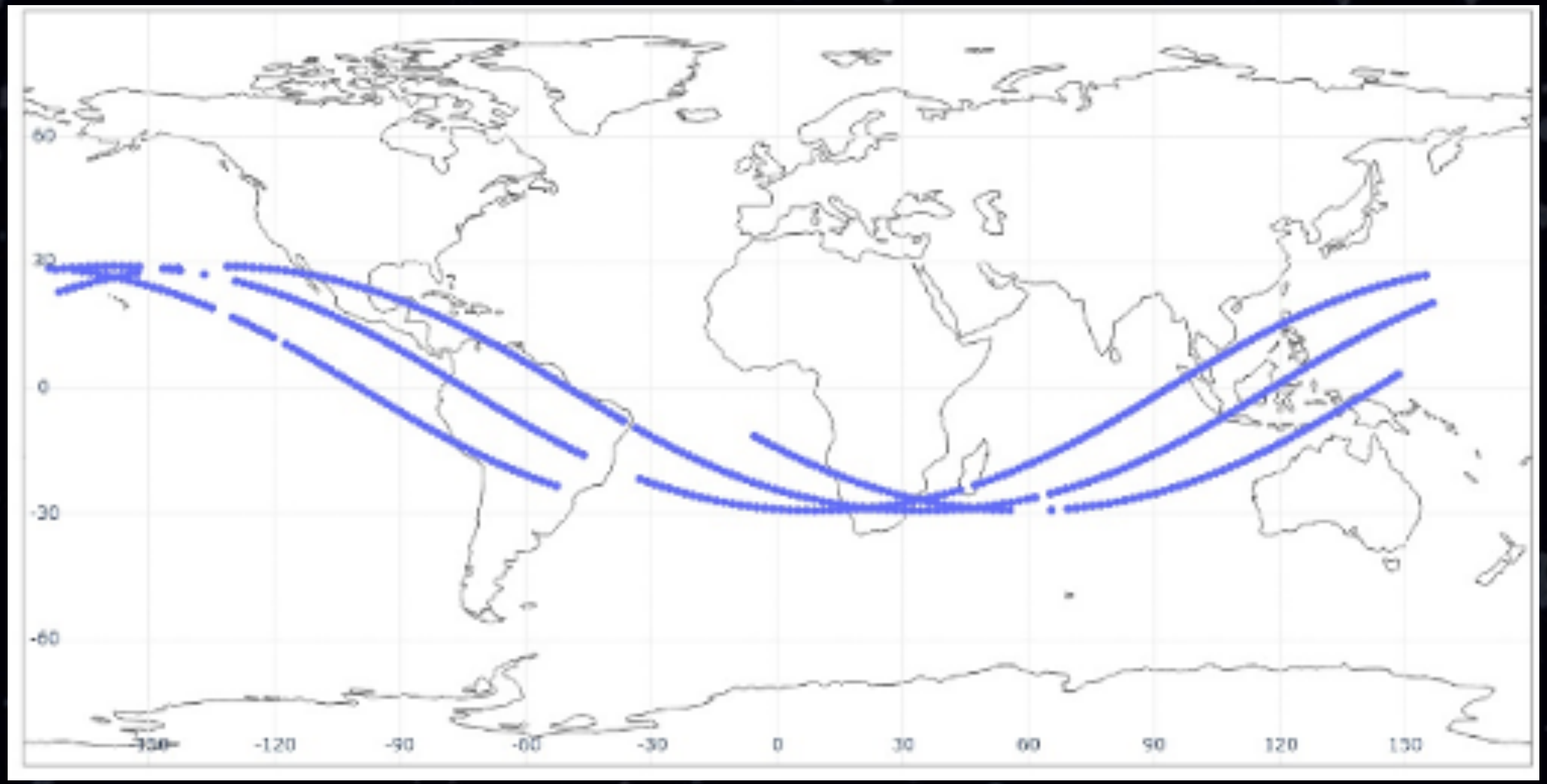
C-GFT
(400 - 950 nm)
FoV: 21’ x 21’
Diam.: 1.2 m
mlim ~ 19 (R - 100 s)

FM-GFT (COLIBRÍ)
(400 - 1700 nm)
FoV: ~ 26’ (diam.)
Diam.: 1.3 m
mlim ~ 20.5 (r - 60 s)

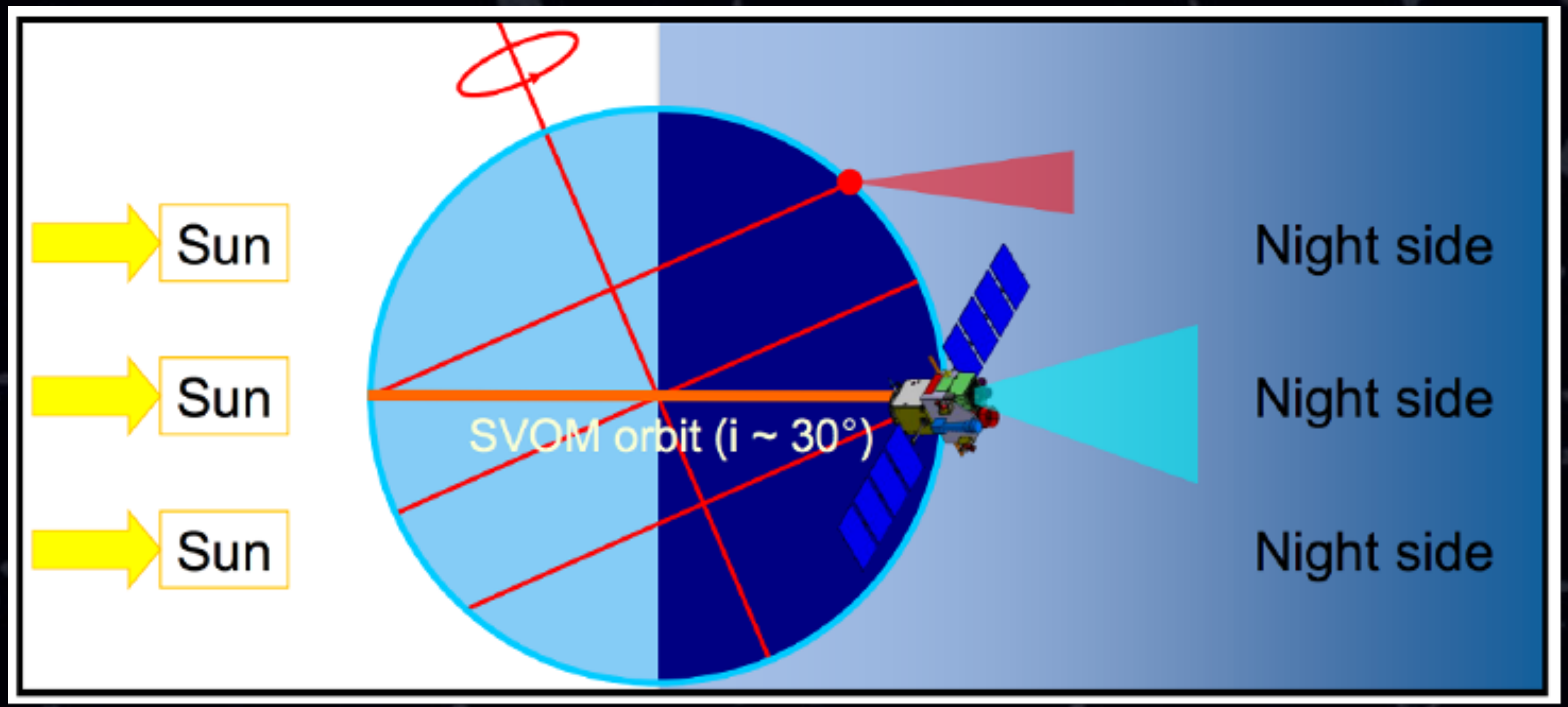
Background image credit: Hello, Is This Planet Earth? - Tim Peake

Orbit and pointing strategy

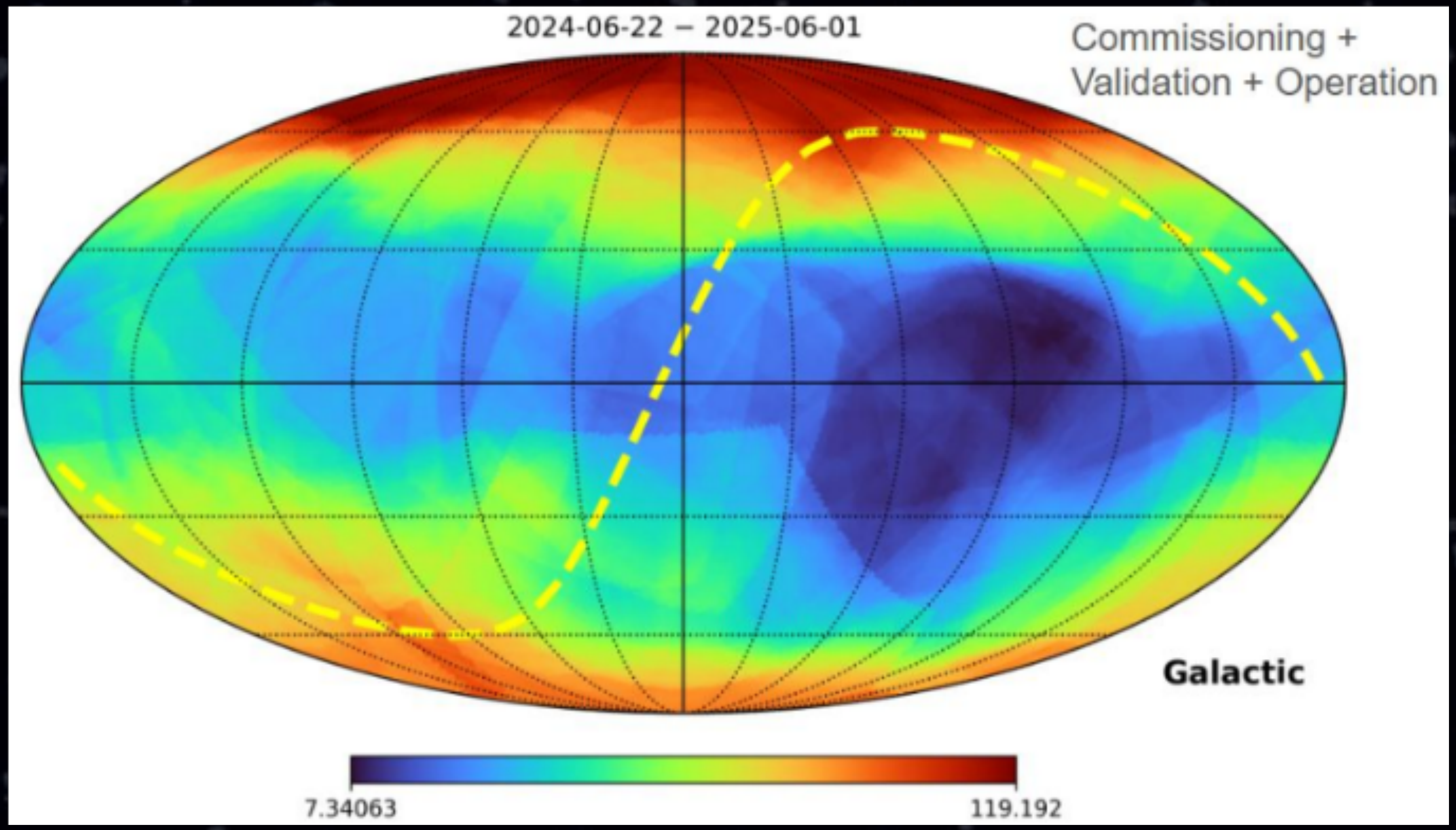
Low Earth Orbit: 625 km, 29° inclination, 96 min per orbit

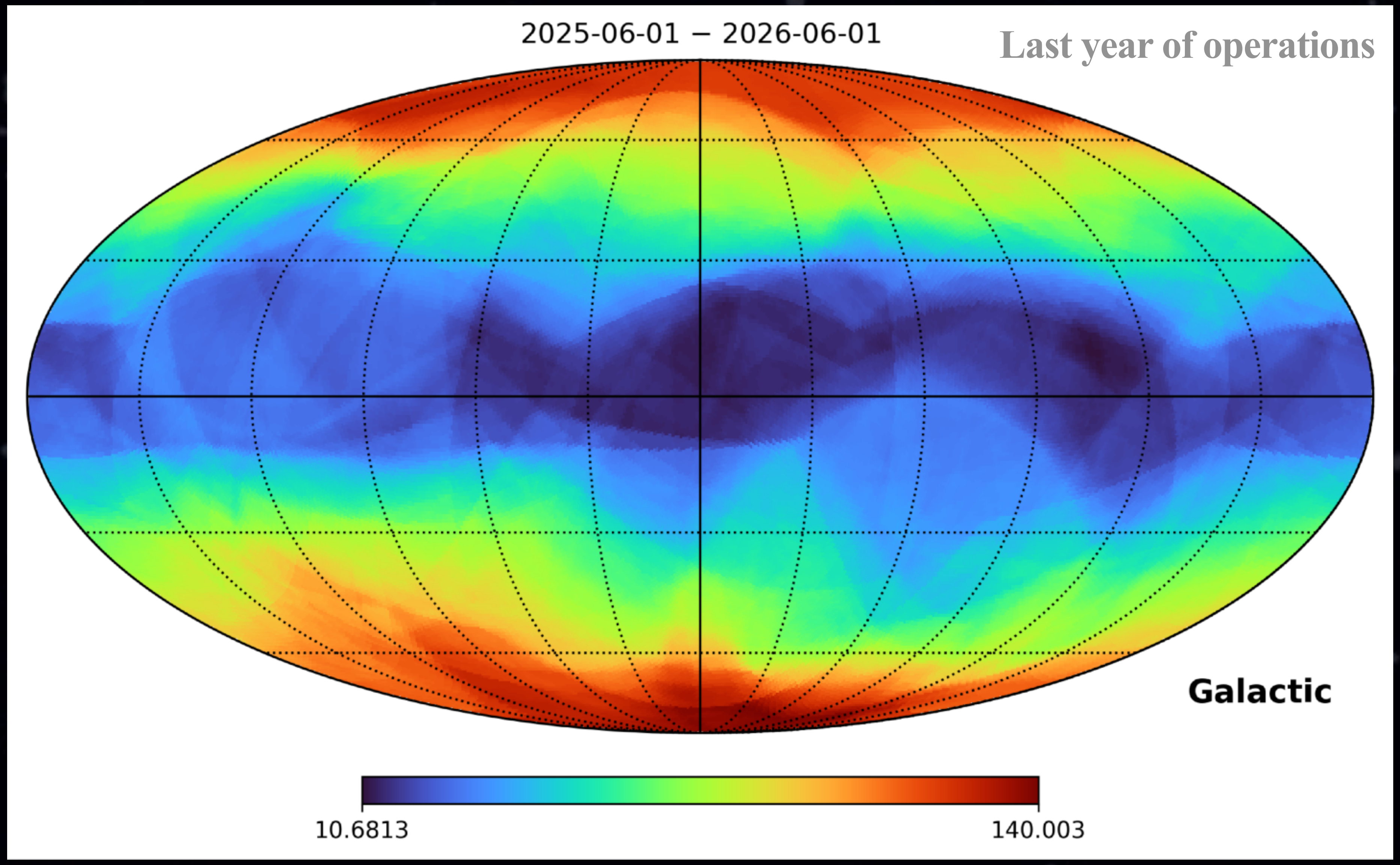


Anti-solar pointing to optimize follow-up



B1 pointing law: avoiding the Galactic plane

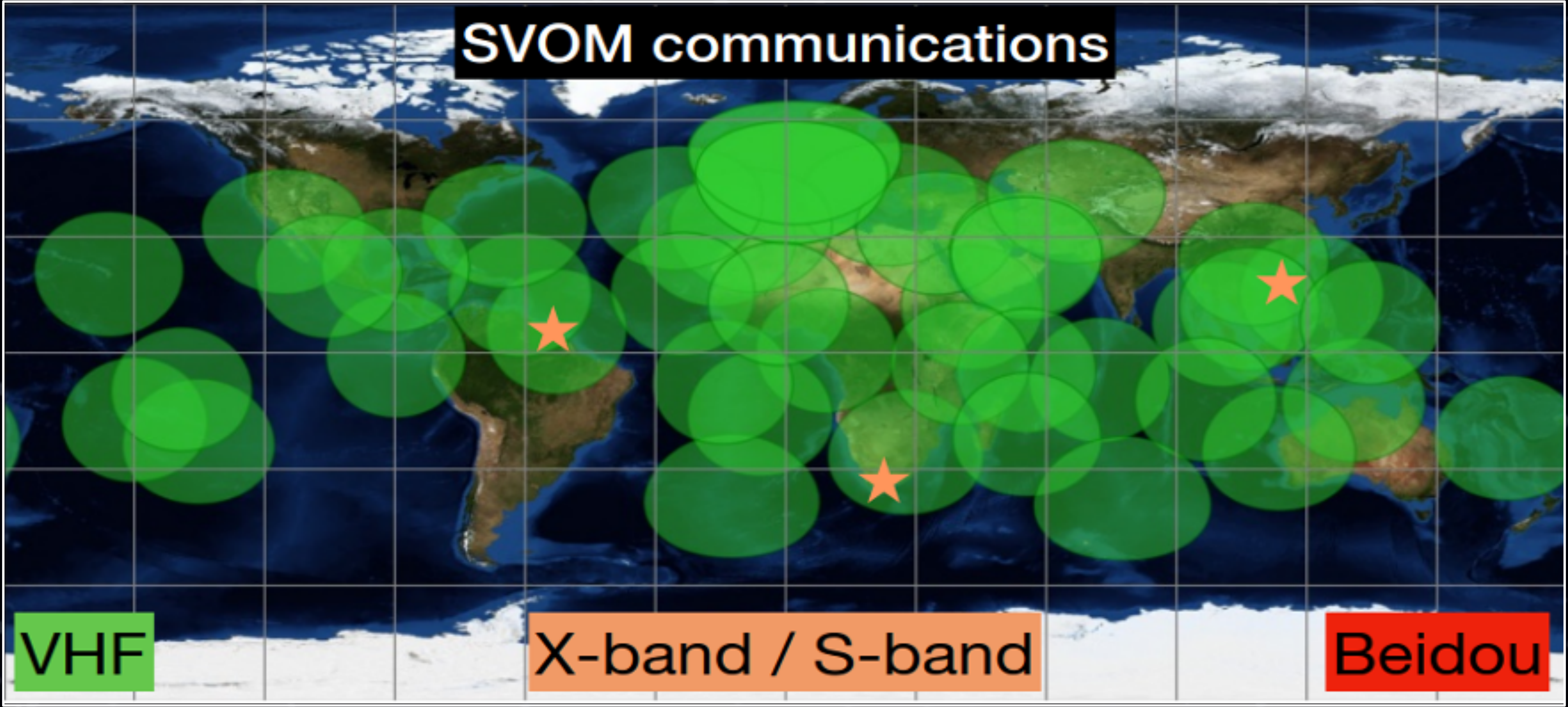




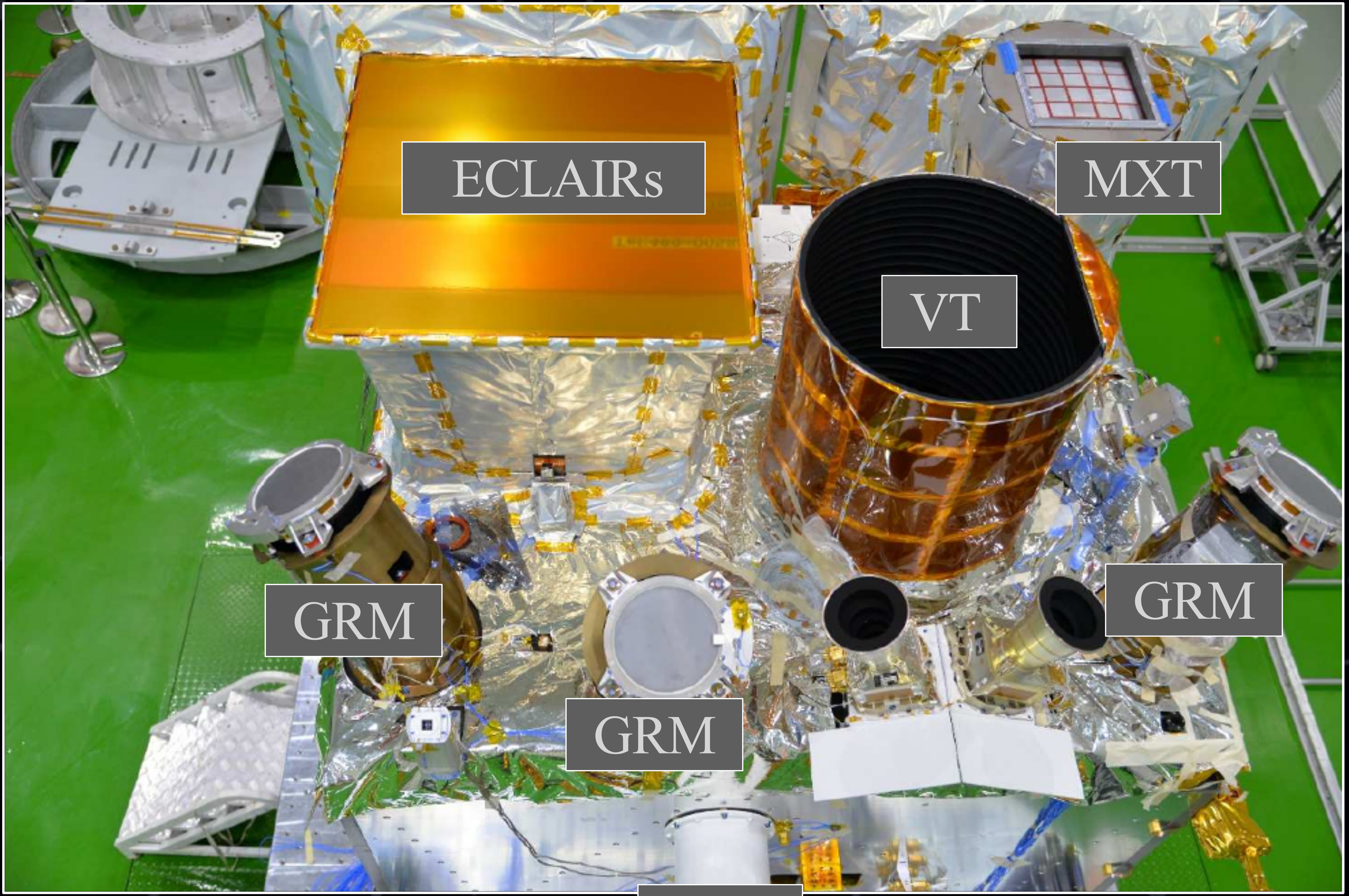
The VHF alert network

- 47 VHF stations deployed under the satellite track
- Alerts are received on the ground (French Science Center) with a median delay of ~**7.6 s**

VHF antenna

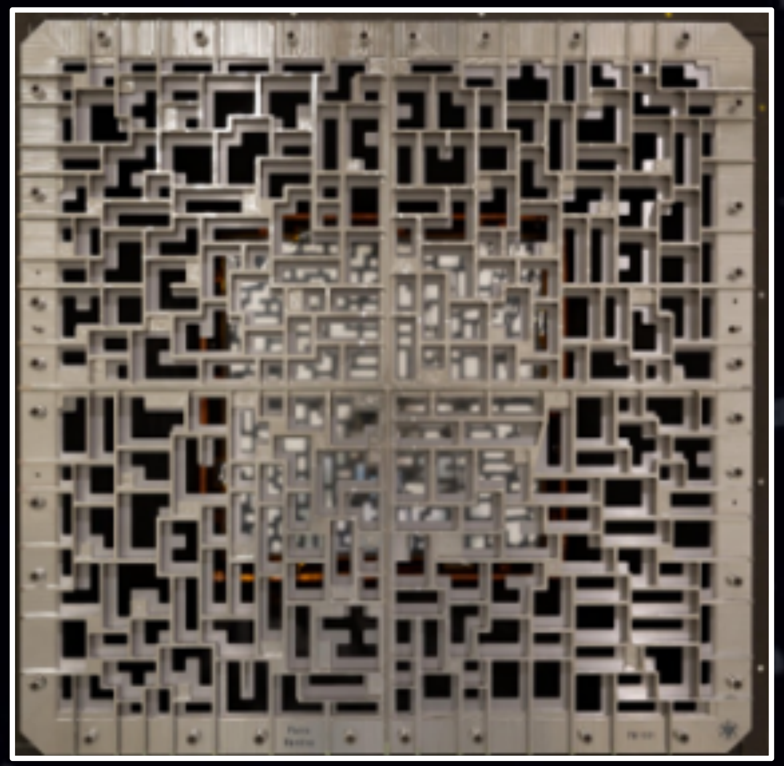


The SVOM satellite payload

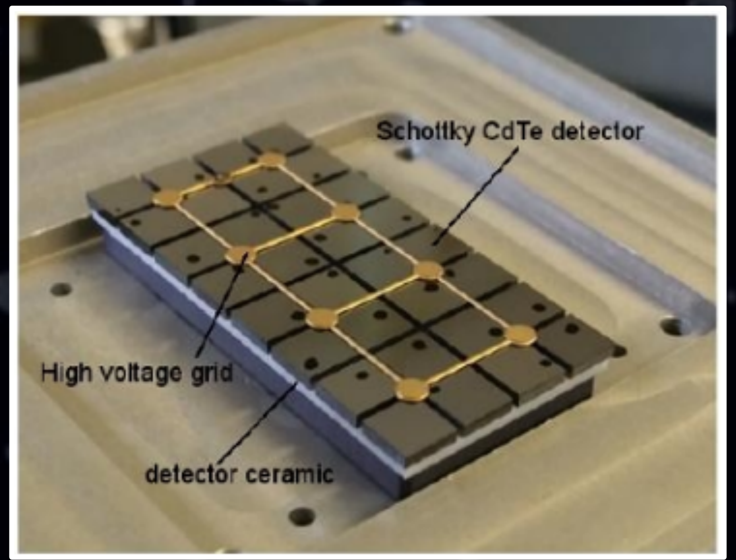


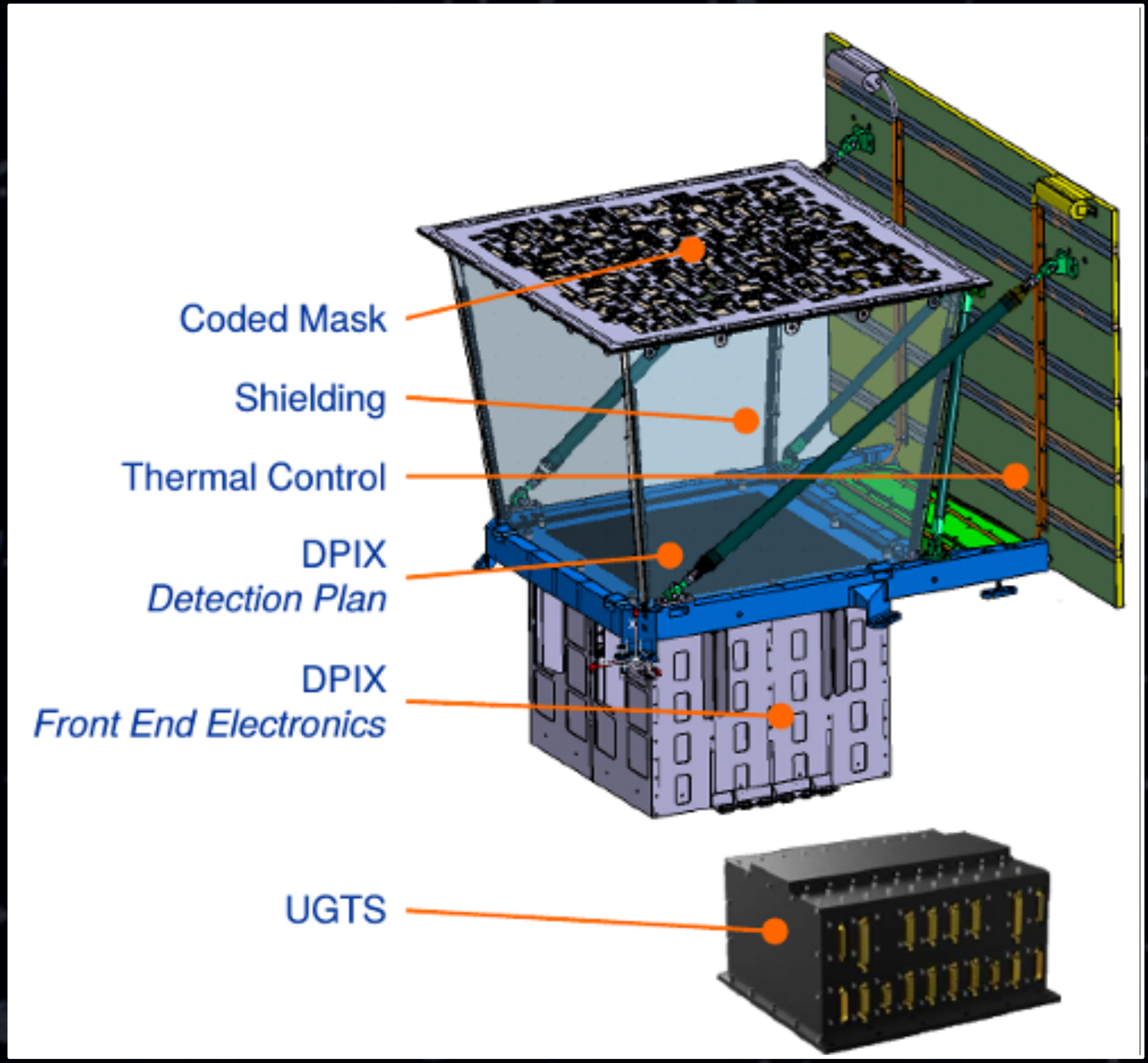
The ECLAIRs X/γ-ray imager

Coded mask

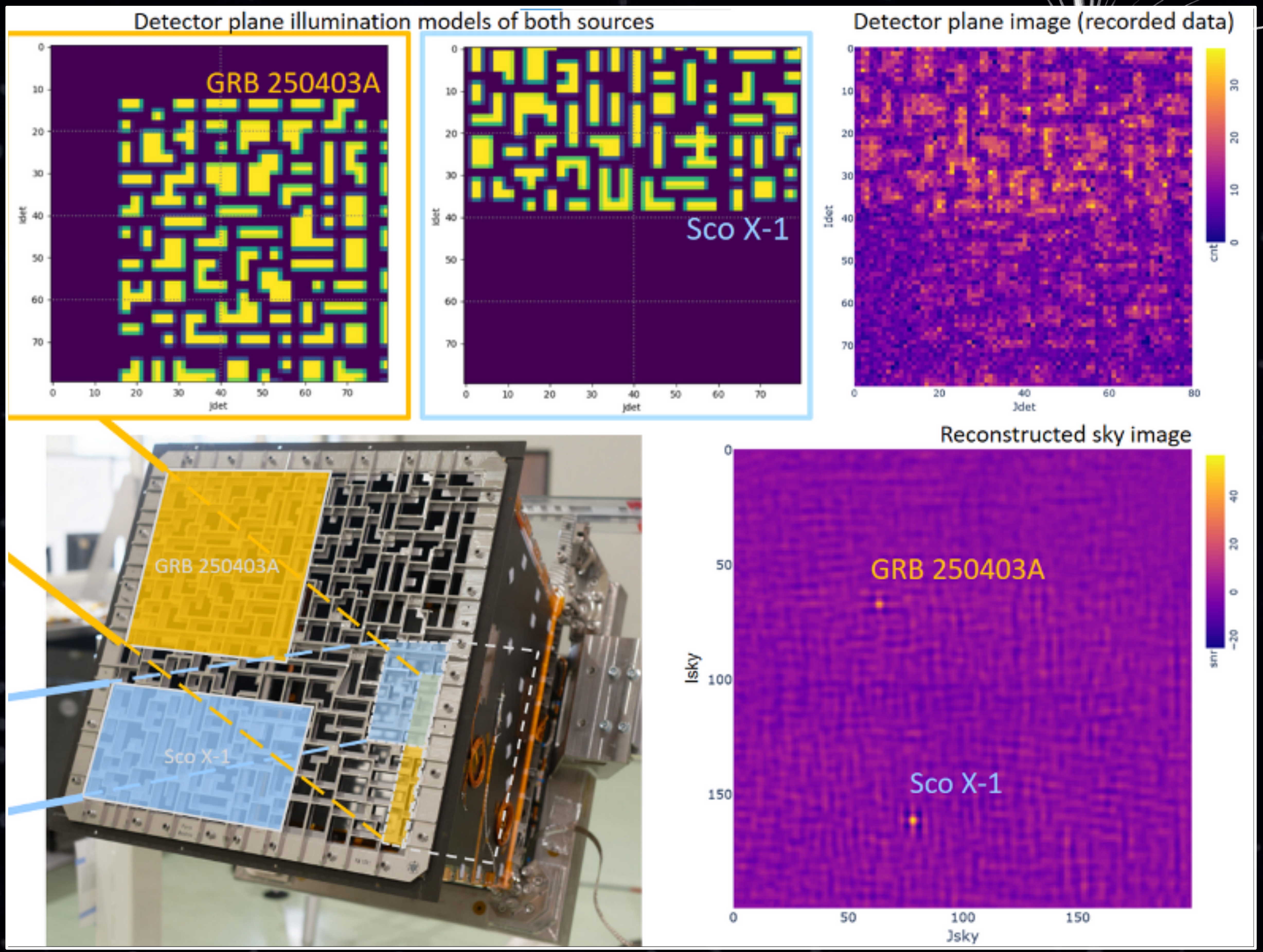


Detector unit





Credit: S. Schanne

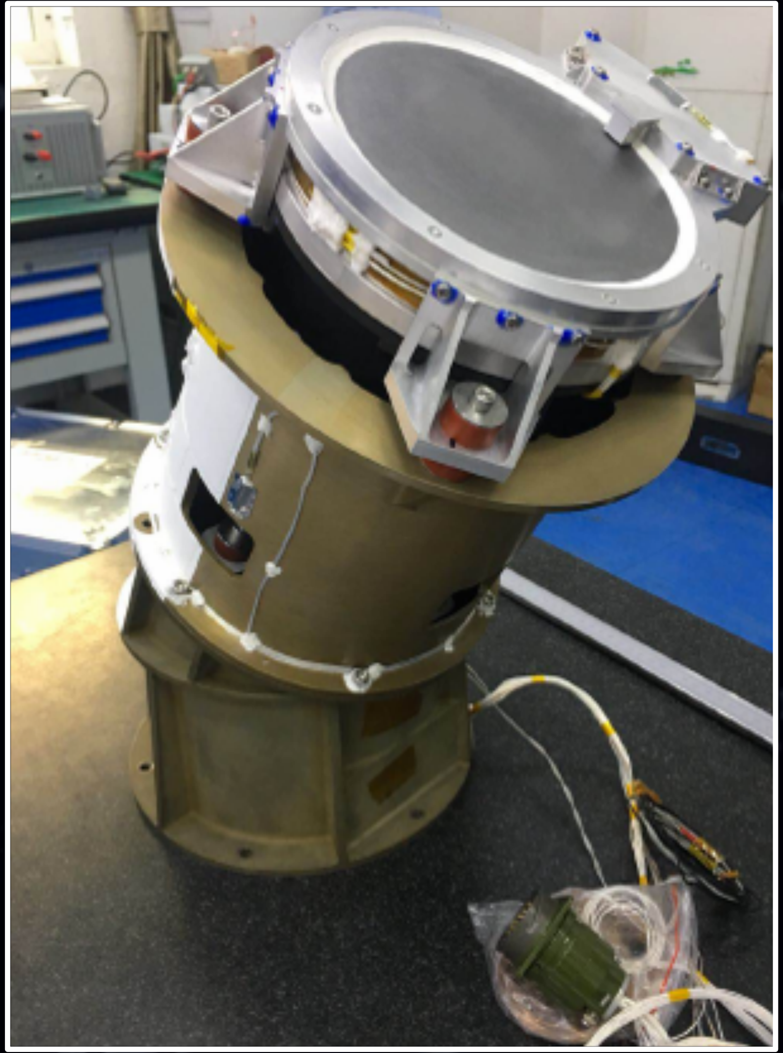


Field of view	2.05 sr (89°x89°)
Energy range	<u>**4**</u>-150 keV
Energy resolution	<1.2 keV @60 keV
Effective area	200 cm² @6 keV
Localization accuracy	**<12 arcmin** (90% of sources at detection limit). Syst. ~2 arcmin

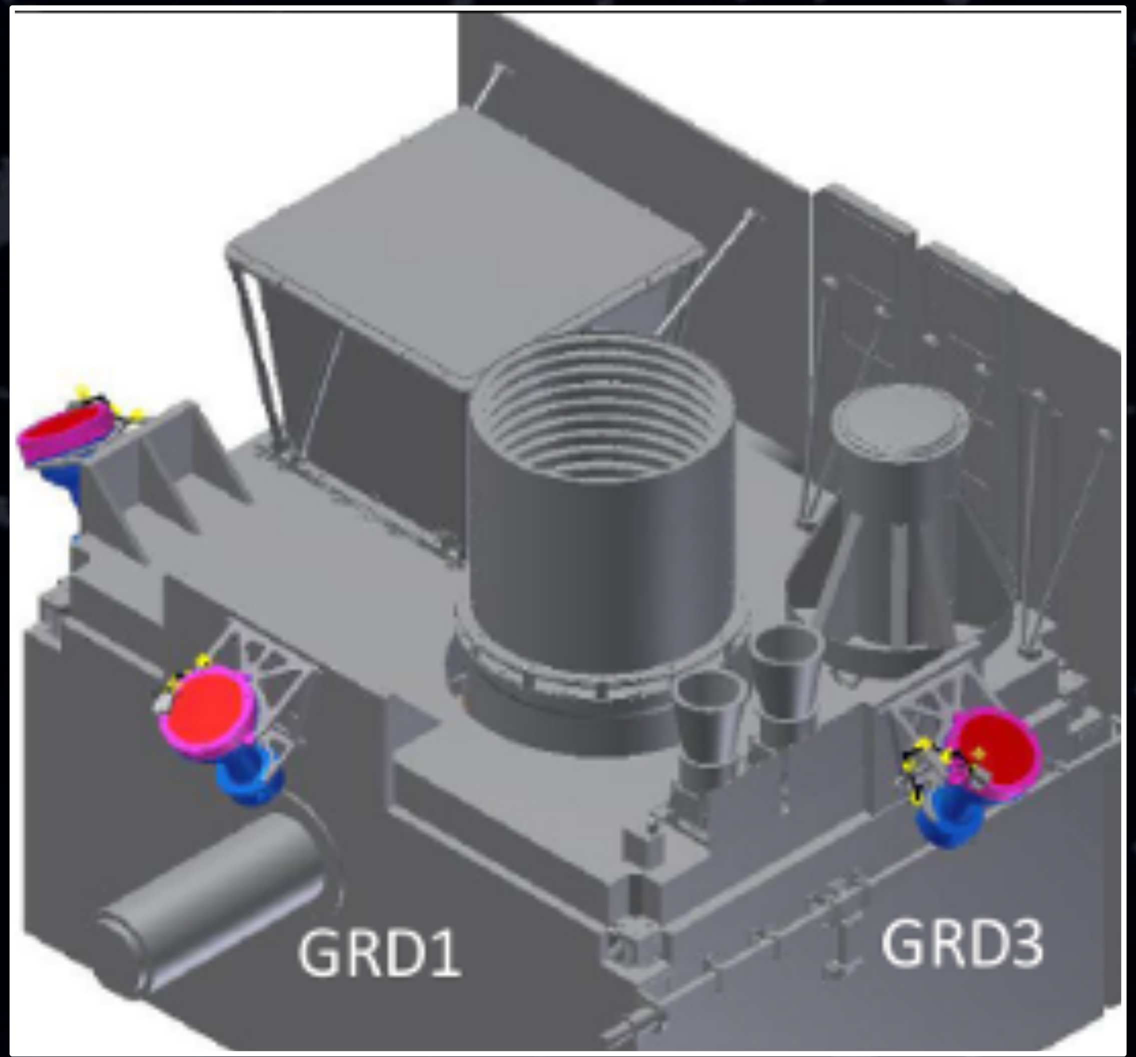
- Onboard real-time trigger and localization (if $SNR_i > 6.5$)
  - Strongly varying background (Earth transit through FoV every orbit)
  - Time scales from 10 ms to <u>**20 min**</u>, 4 energy bands, 9 detector zones
  - Count Rate Trigger (CRT, ≤ 20 s) and Image Trigger (IMT, ≥ 20 s)
- Slew request within ~25 s (if $SNR_i > 7$)

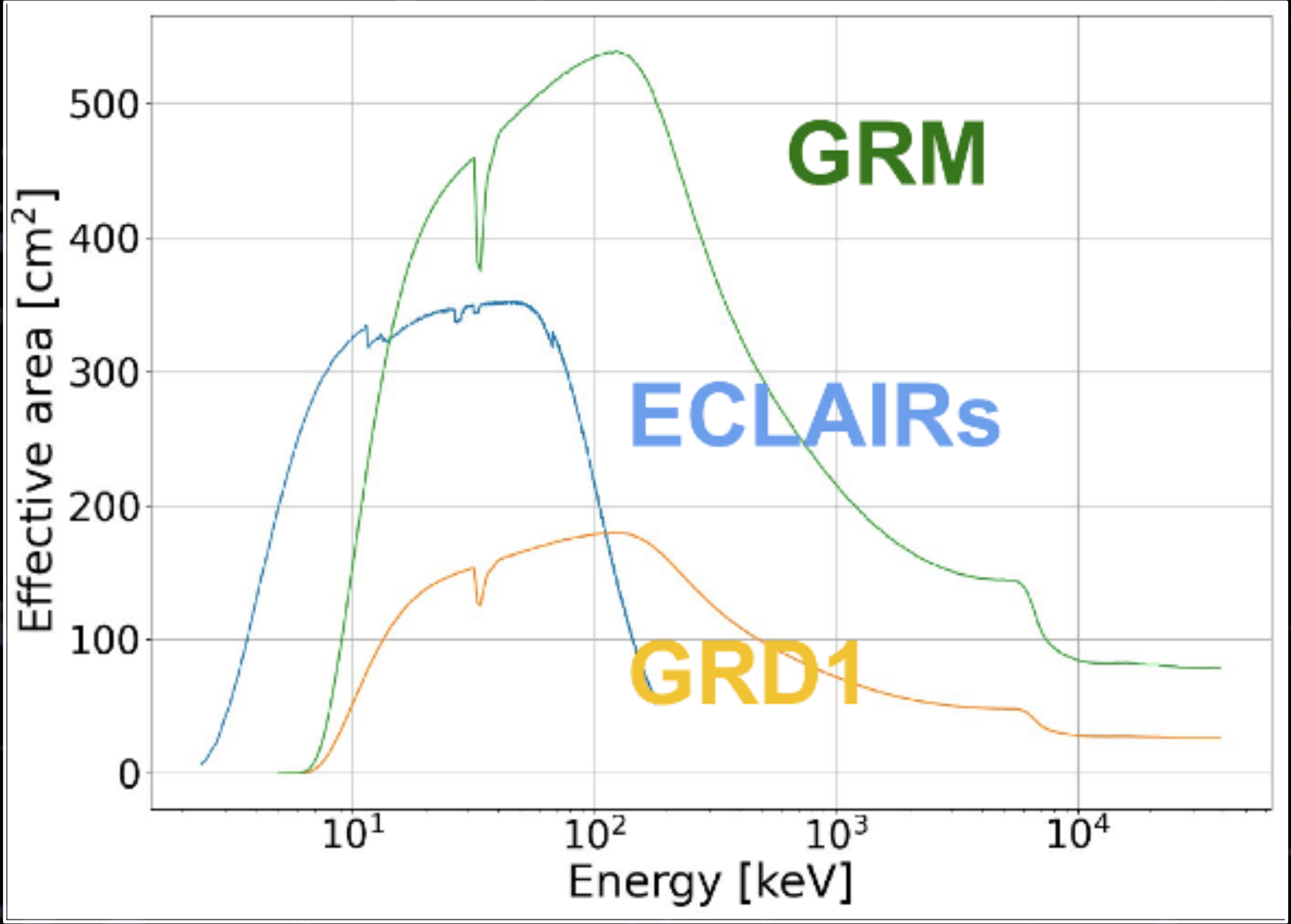
The Gamma-Ray Monitor (GRM)

Single GRD



The 3 GRDs on the payload



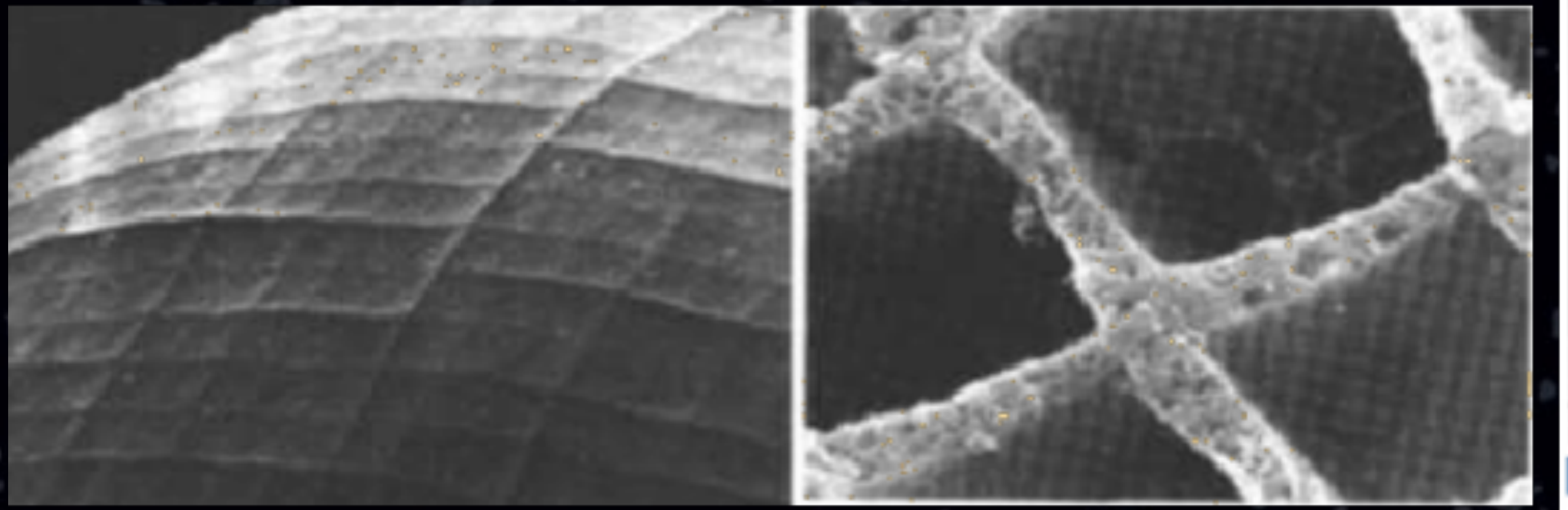


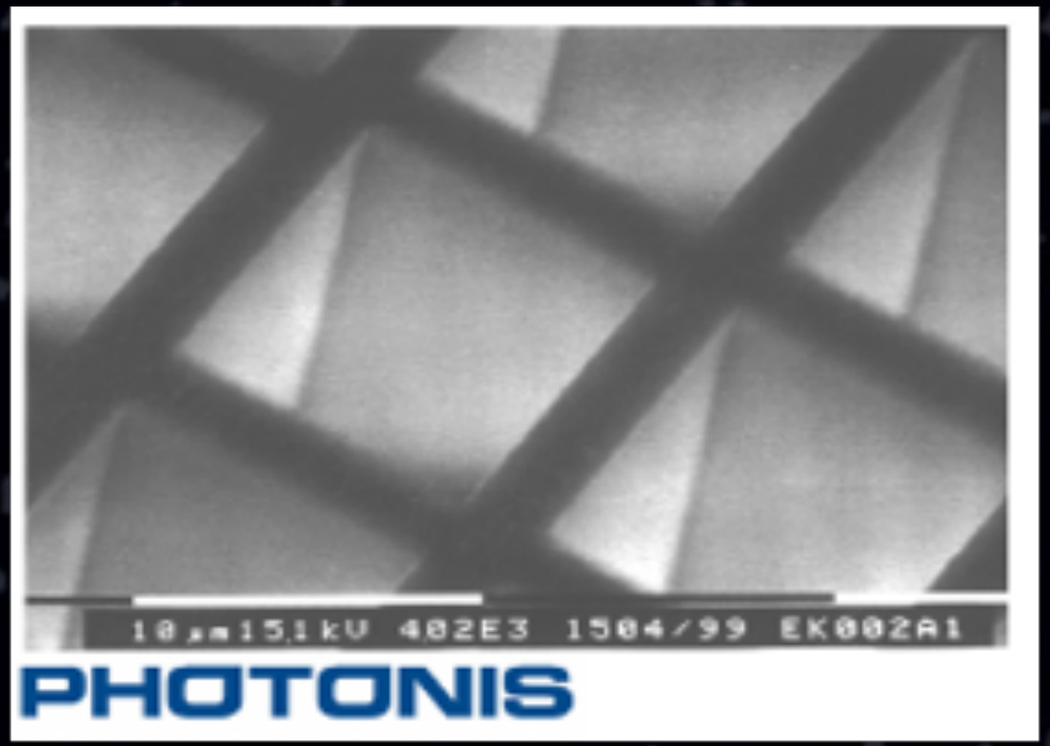
Field of view	5.6 sr (GRD ±60°)
Energy range	15-**5000** keV
Energy resolution	<19% @60 keV
Effective area	190 cm² @peak for each GRD
Localization accuracy	Several degrees (under study)

- 3 Gamma-Ray Detectors (GRDs)
  - NaI(Tl) (16 cm Ø, 1.5 cm thick)
  - 30° inclination w.r.t. ECLAIRs optical axis
- Count Rate Trigger (2 GRDs above threshold)
  - Time scales 0.1 to 4 s, 4 energy bands

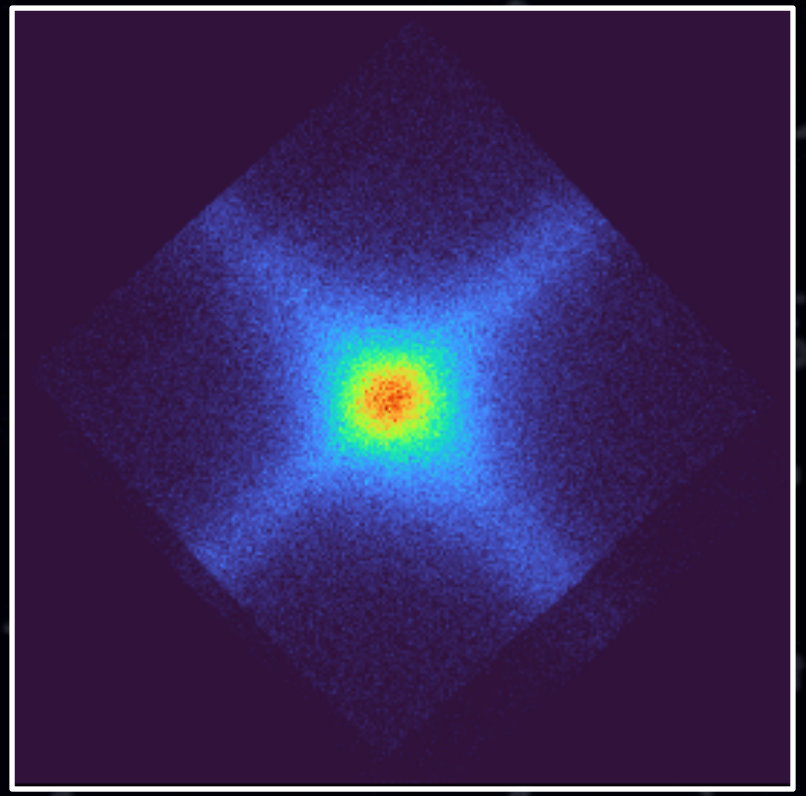
The Microchannel X-ray Telescope (MXT)

Real vs manufactured "Lobster eyes"

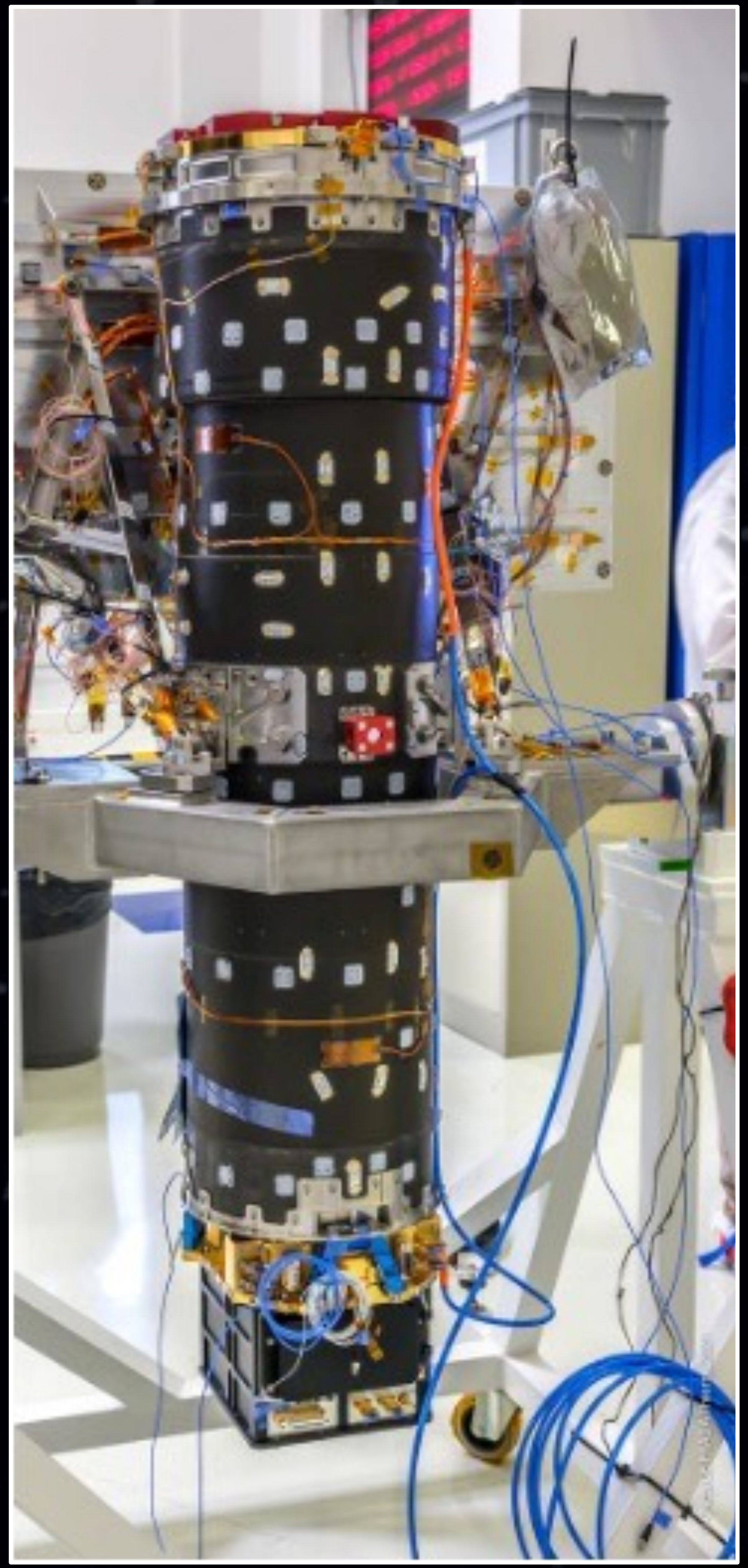




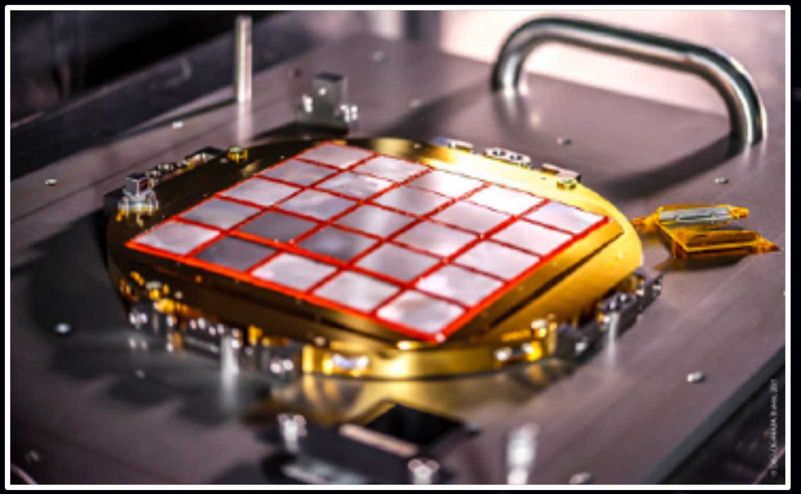
MXT PSF



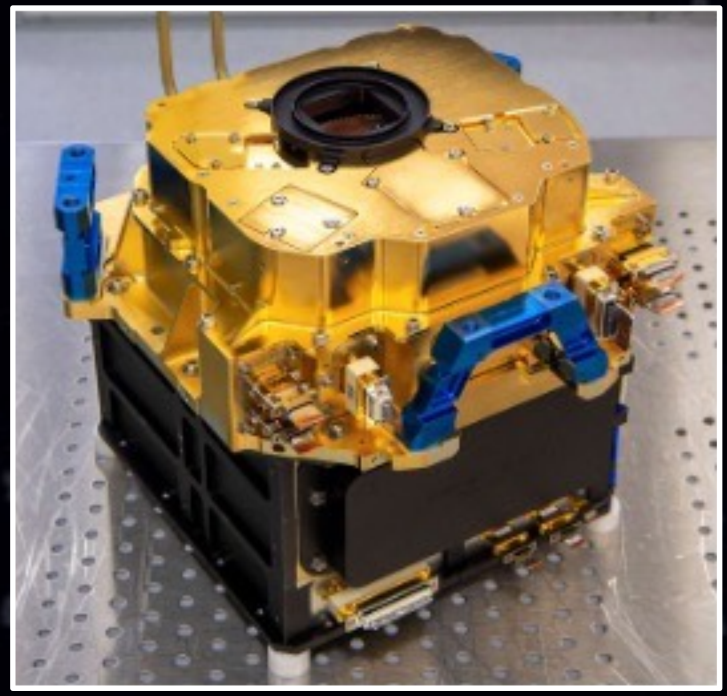
Tube



Optics



Camera

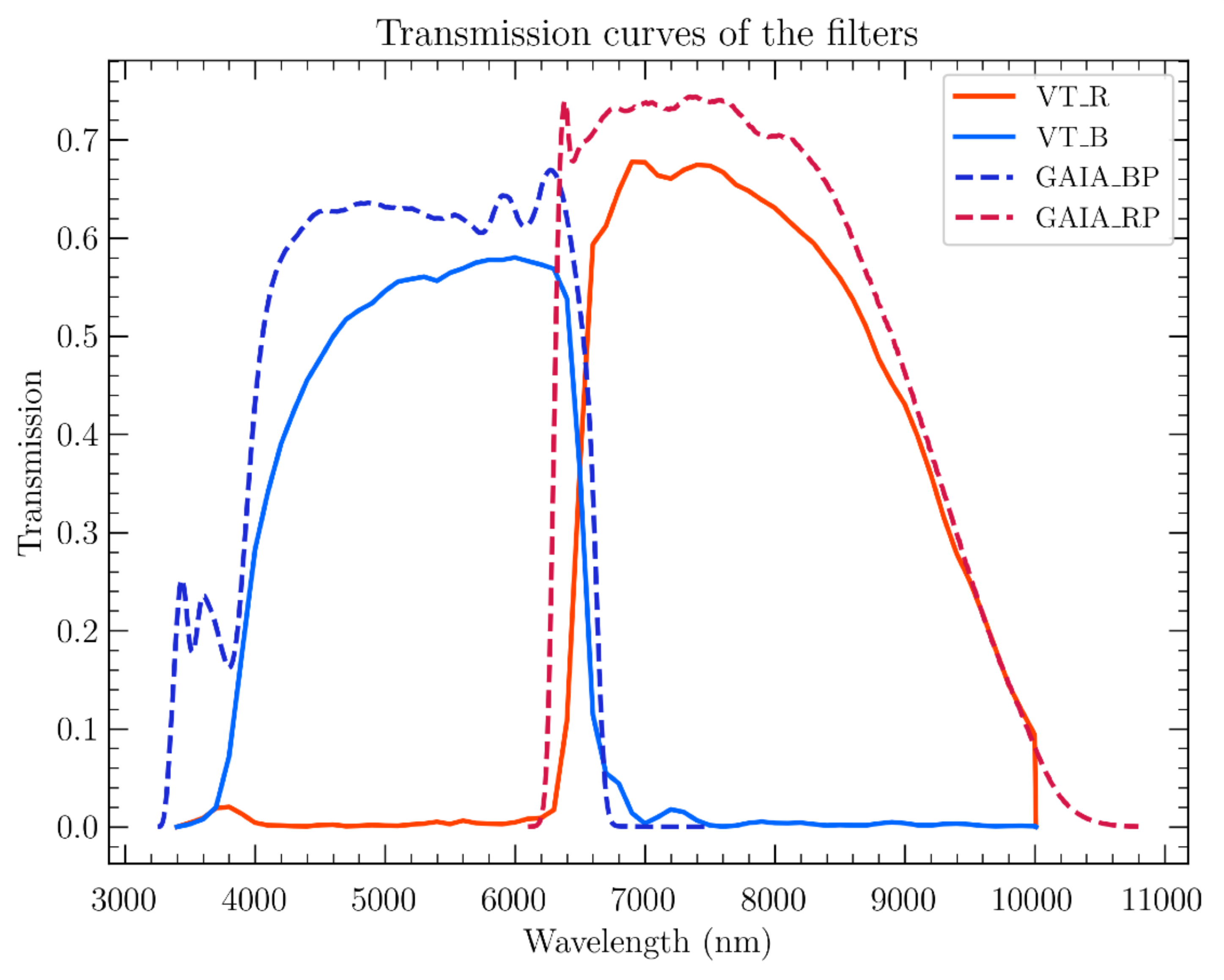


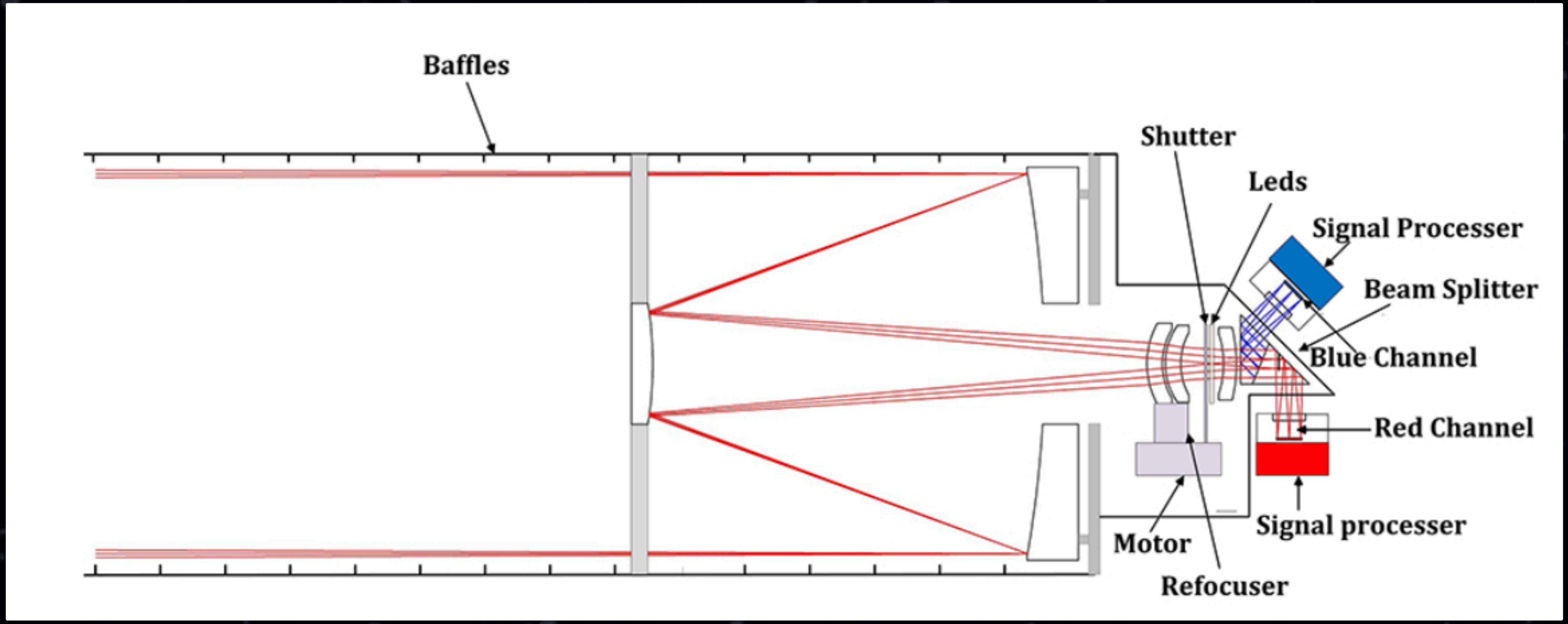
Field of view	**58x58 arcmin²**
Energy range	0.2-10 keV
Energy resolution	80 eV (FWHM) @1 keV
Effective area (@1 keV)	27 cm² central spot 35 cm² incl. arms
Localization accuracy	<1 arcmin (50%) **<2 arcmin** (90%) Syst. ~15 arcsec

- Micro-channel plate optics (0.2-10 keV)
  - 40 micron size pores in a "lobster eye" configuration
  - Focal length: 1.15 m
  - pnCCD camera (256x256 pixels of 75 microns), cooled at -65°C. State of the art spectral resolution

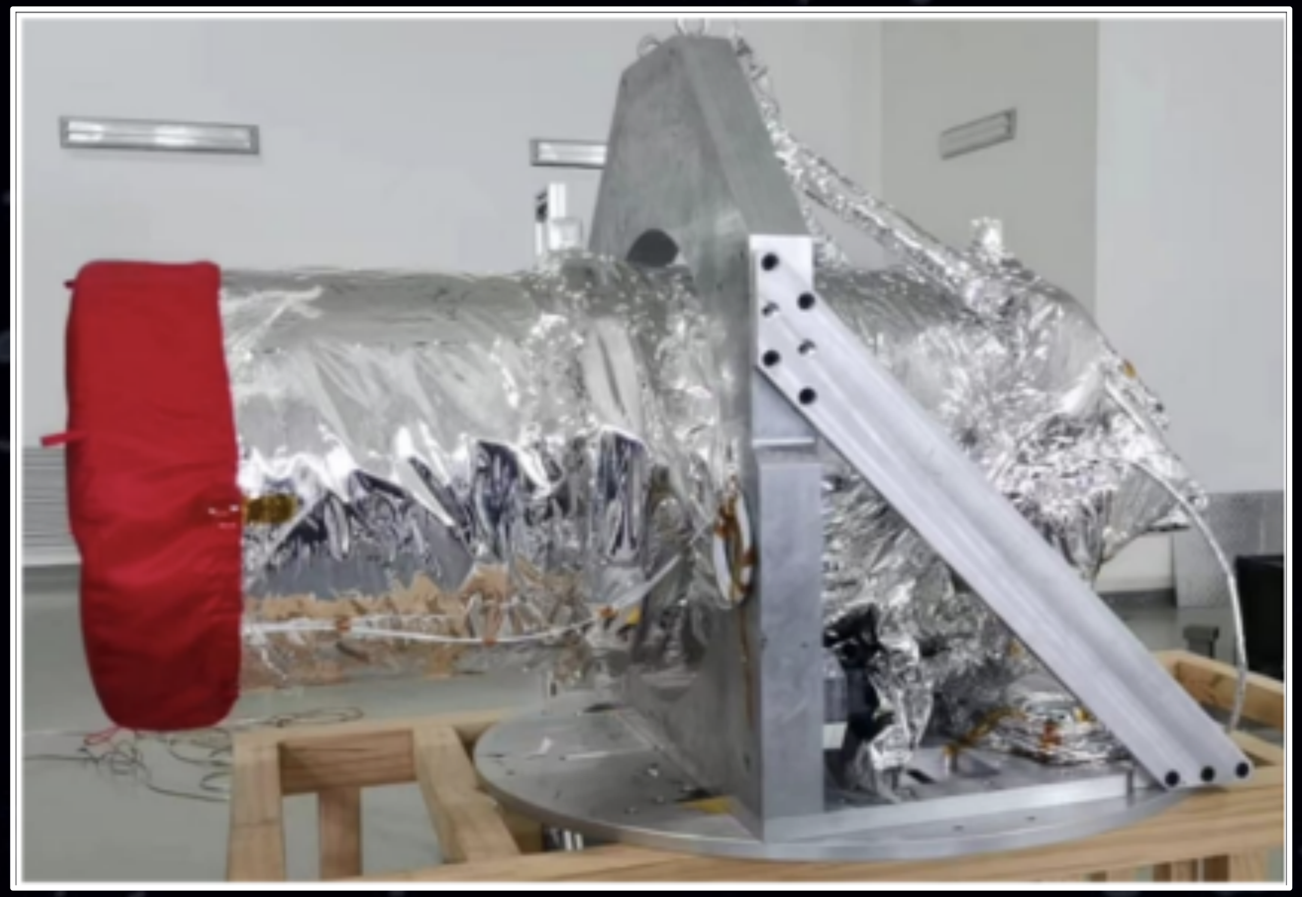
The Visible Telescope (VT)

VT filters vs Gaia





VT before assembly on the satellite



Field of view	**26x26 arcmin²**
Sensitivity	Mv = 22.7 (B/R) (3σ, 300 s) Mv ~ 24 (stacking)
Localization accuracy	B: 80% @1.4 arsec R: 70% @0.9 arsec
Photometry accuracy	Blue: 1.3% Red: 0.5%

- Ritchey-Chrétien telescope
  - 44 cm Ø, f=9
  - Focal length: 3.6 m
  - 2 channels: **blue** (400-650 nm) and **red** (650-1000 nm)
  - 2k×2k CCD detector each
- FoV covering ECLAIRs error box in most cases

Ground-based dedicated follow-up

- Ground Follow-up Telescopes (GFTs)
  - Robotic 1-m class telescopes (fast repointing, < 30 s)
  - San Pedro Martir (Mexico) and Xinglong observatory (China)
  - C-GFT: 1.2 m, FoV = 21x21 arcmin^2, 400-950 nm
  - FM-GFT (a.k.a. COLIBRÍ): 1.3 m, FoV = 26x26 arcmin^2
    - Multi-band photometry (400-**1700** nm, 3 simultaneous bands)
    - A new camera (CAGIRE) to be installed in coming months, allowing observations in **J&H** bands

FM-GFT / COLIBRÍ

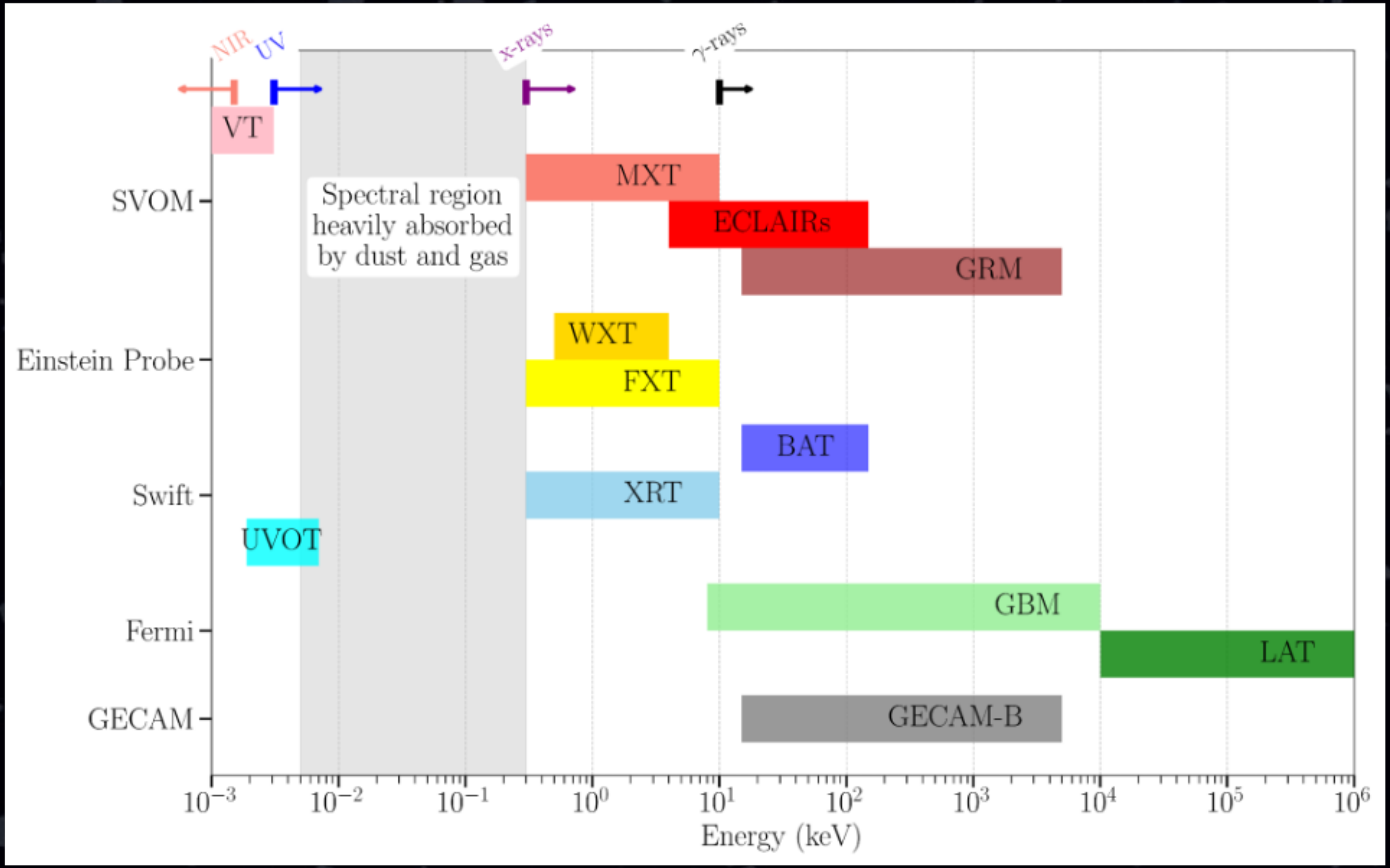
C-GFT

- Ground-based Wide Angle Camera (GWAC)
  - 40 camera units covering 3600 deg^2 (> 1/3 ECLAIRs FoV)
  - Installed in Ali (China) and CTIO (Chile)
  - 500-800 nm; Mlim = 16 (10 s exposure)
  - Explore the prompt optical emission

GWAC

+ LCO Las Cumbres Observatory

GRB mission landscape



SVOM's design choices

- Good prompt coverage:
  - 4 keV → 5 MeV
- Fast, sensitive optical/NIR follow-up:
  - $m_V \sim 22.5$ @ 300s (VT), $m_r \sim 20.5$ @ 60s (COLIBRÍ)
  - Spectral coverage up to 1 µm (VT) and 1.7 µm (COLIBRÍ/CAGIRE in the next months)
- Dedicated robotic multi-site ground-based follow-up:
  - Minimize bad weather and visibility issues
- Strong implication and cooperation with follow-up collaborations with spectroscopic access to large telescopes
  - GTC
  - Stargate @ VLT

+ synergies with Swift/EP (automatic ToO requests) & other missions

SVOM scientific program

- Two SVOM science working groups:
  - Core Program/GRB science: F. Daigne
  - Observatory Science: A. Coleiro

The SVOM Core program

reserved to SVOM Co-Is

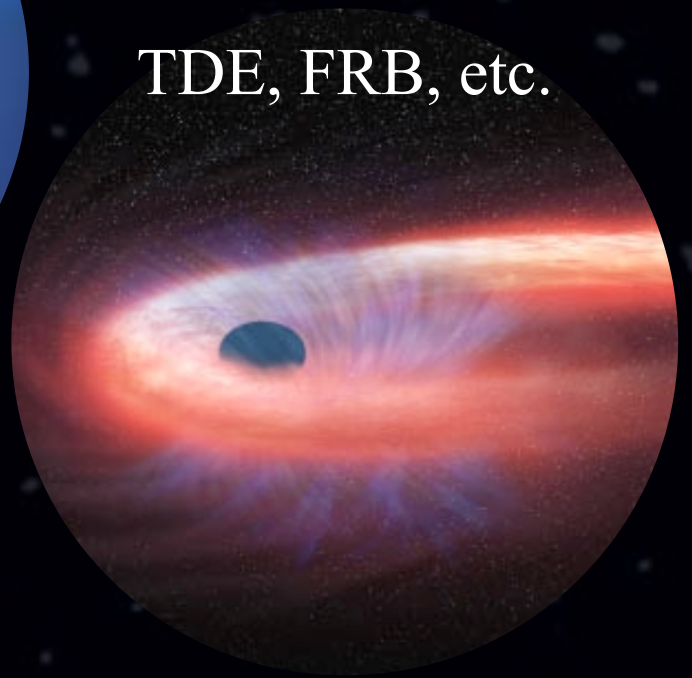
Gamma-Ray Bursts (GRBs)

Observatory Science

Flaring stars

CVs, X-ray binaries

TDE, FRB, etc.



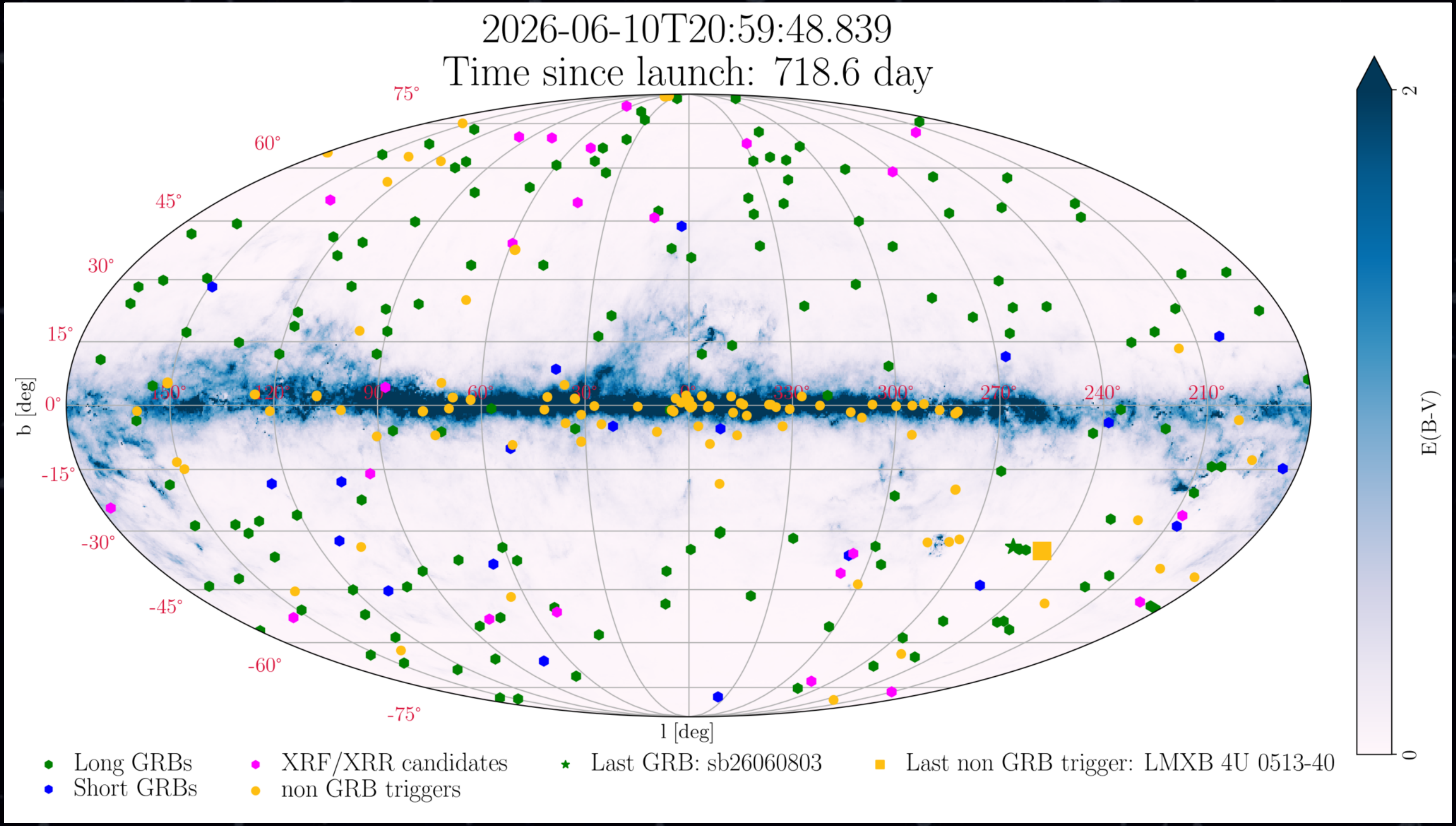
Magnetar Giant flares

Supernovae

AGNs/Blazars

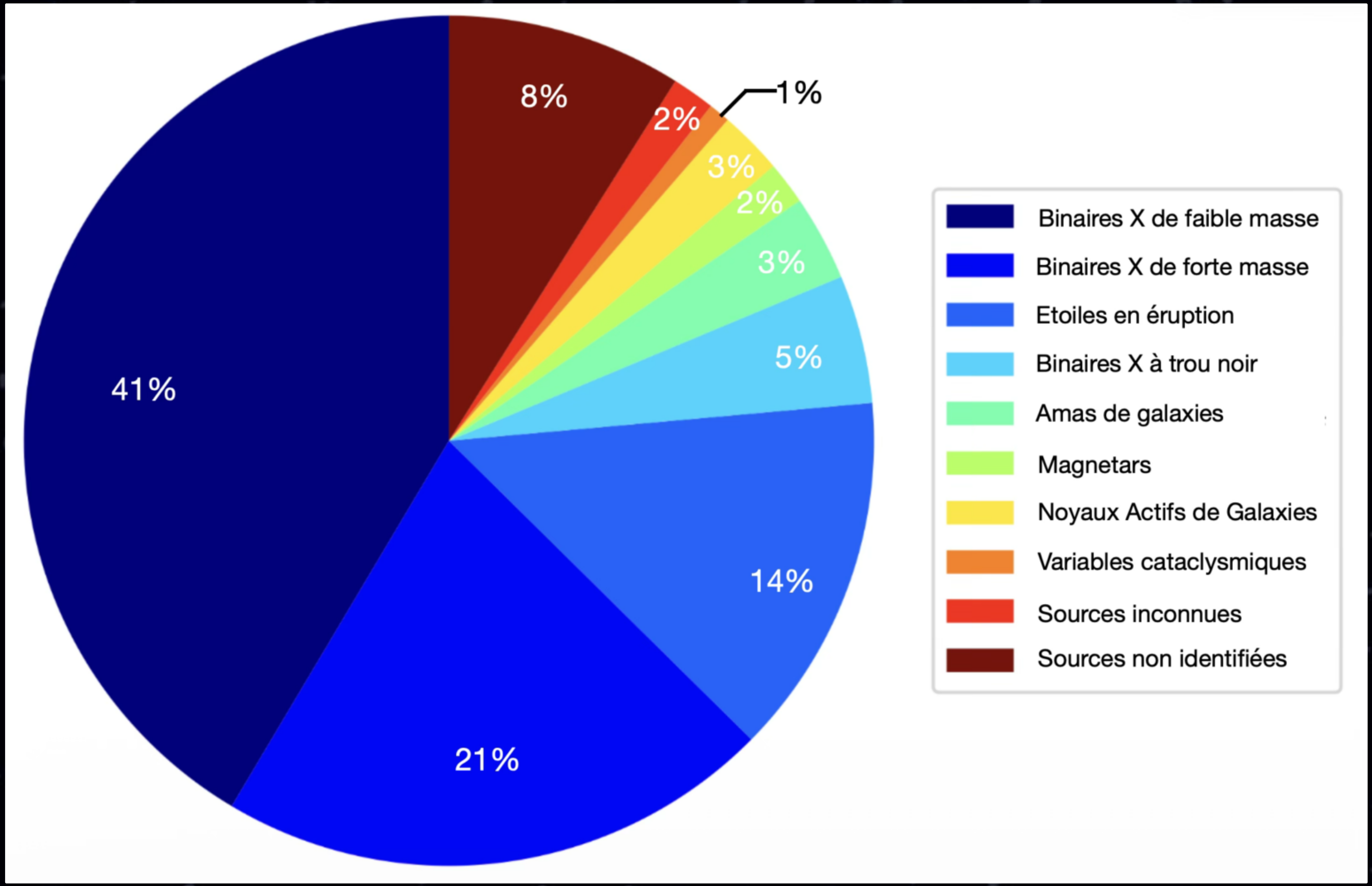
SVOM X/γ-ray transient sources

- More than 400 astrophysical transient sources detected
  - 325 GRBs
  - 96 non-GRB transients



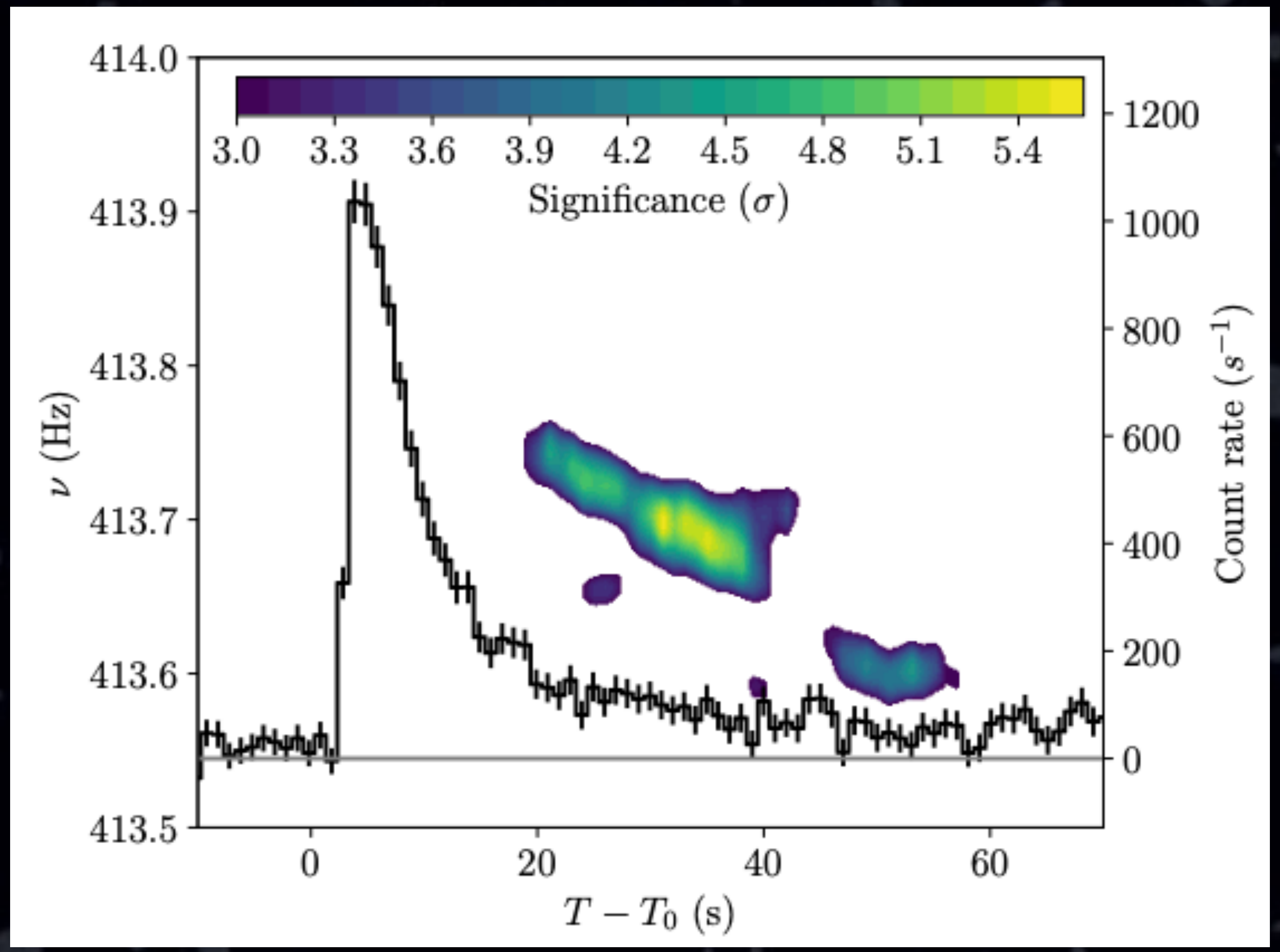
SVOM non-GRB transients

- Majority are in the Galactic plane and identified in most cases
- A diversity of sources but a majority of X-ray binaries

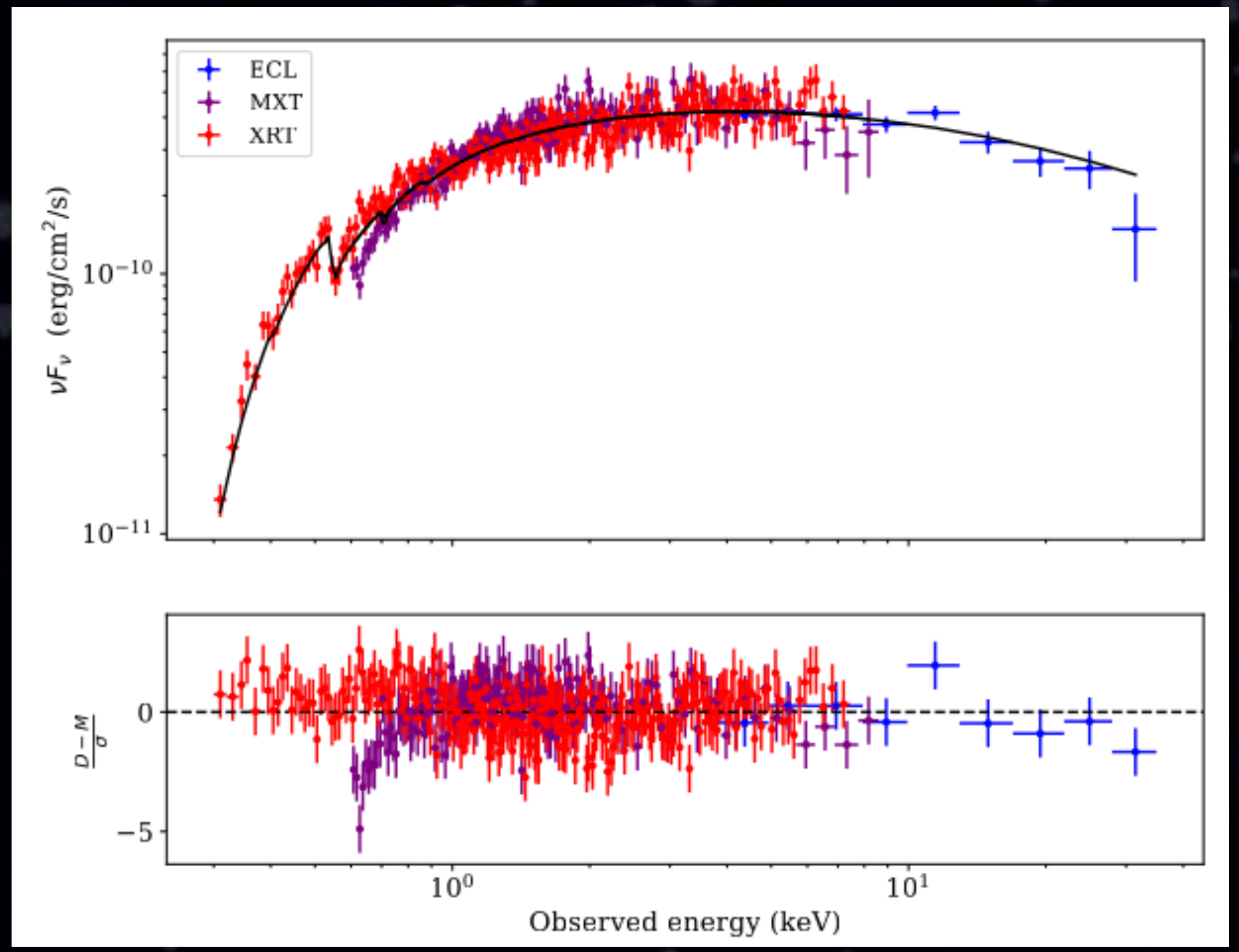


SVOM Observatory Science selected results (credit: Alexis Coleiro)

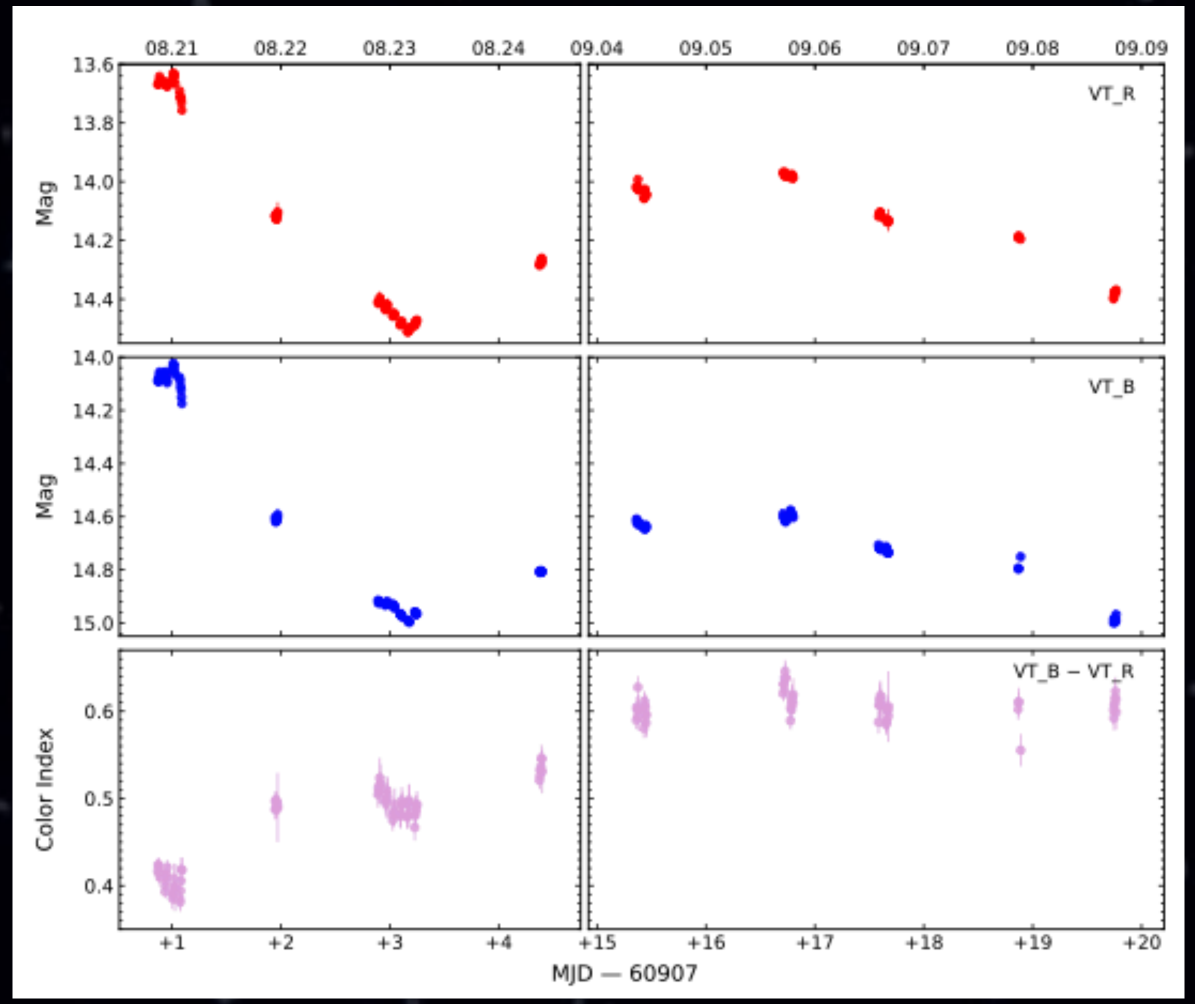
Type I burst of 4U 0614+091 (S. Le Stum et al.)



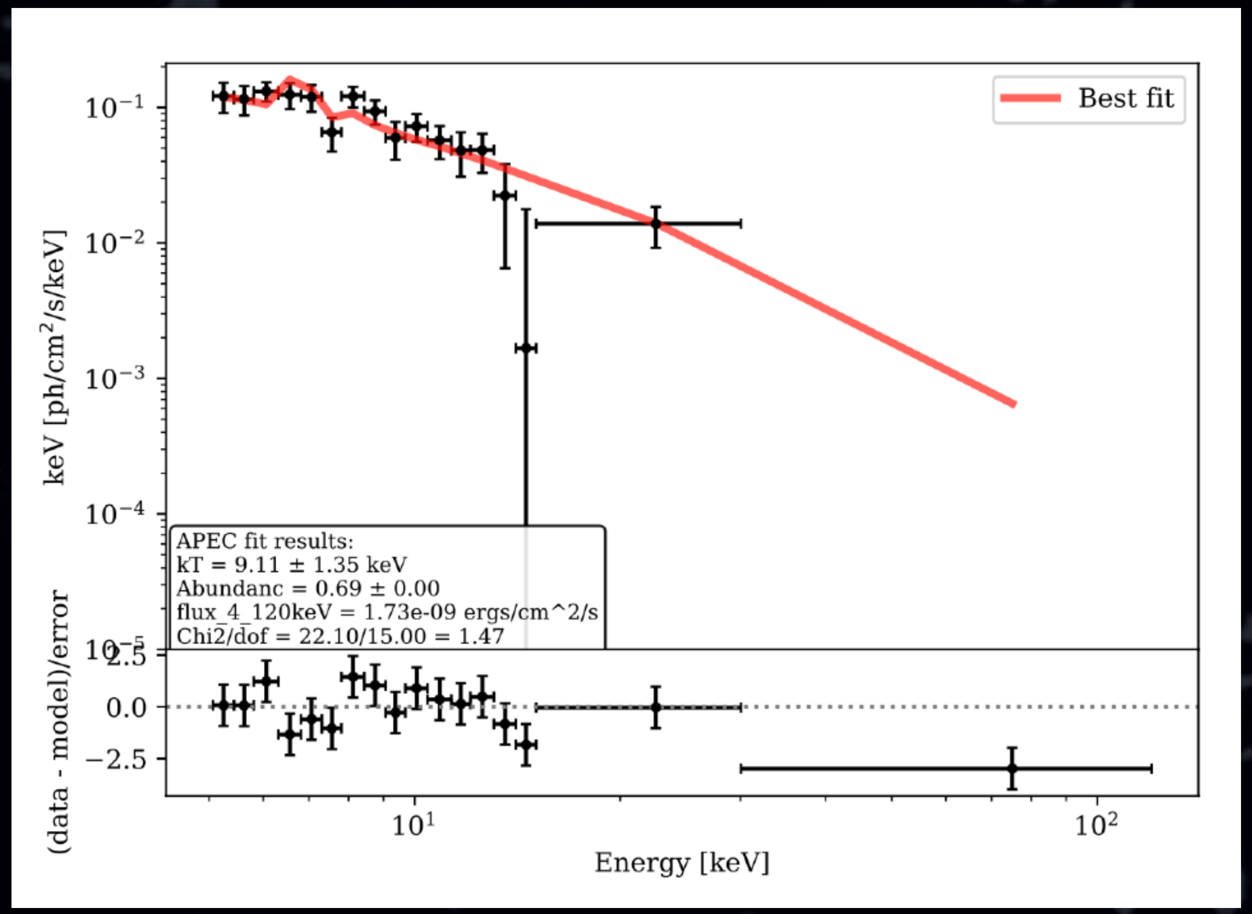
Outburst of 1ES 1959+650 detected by ECLAIRs (A. Foisseau et al.)



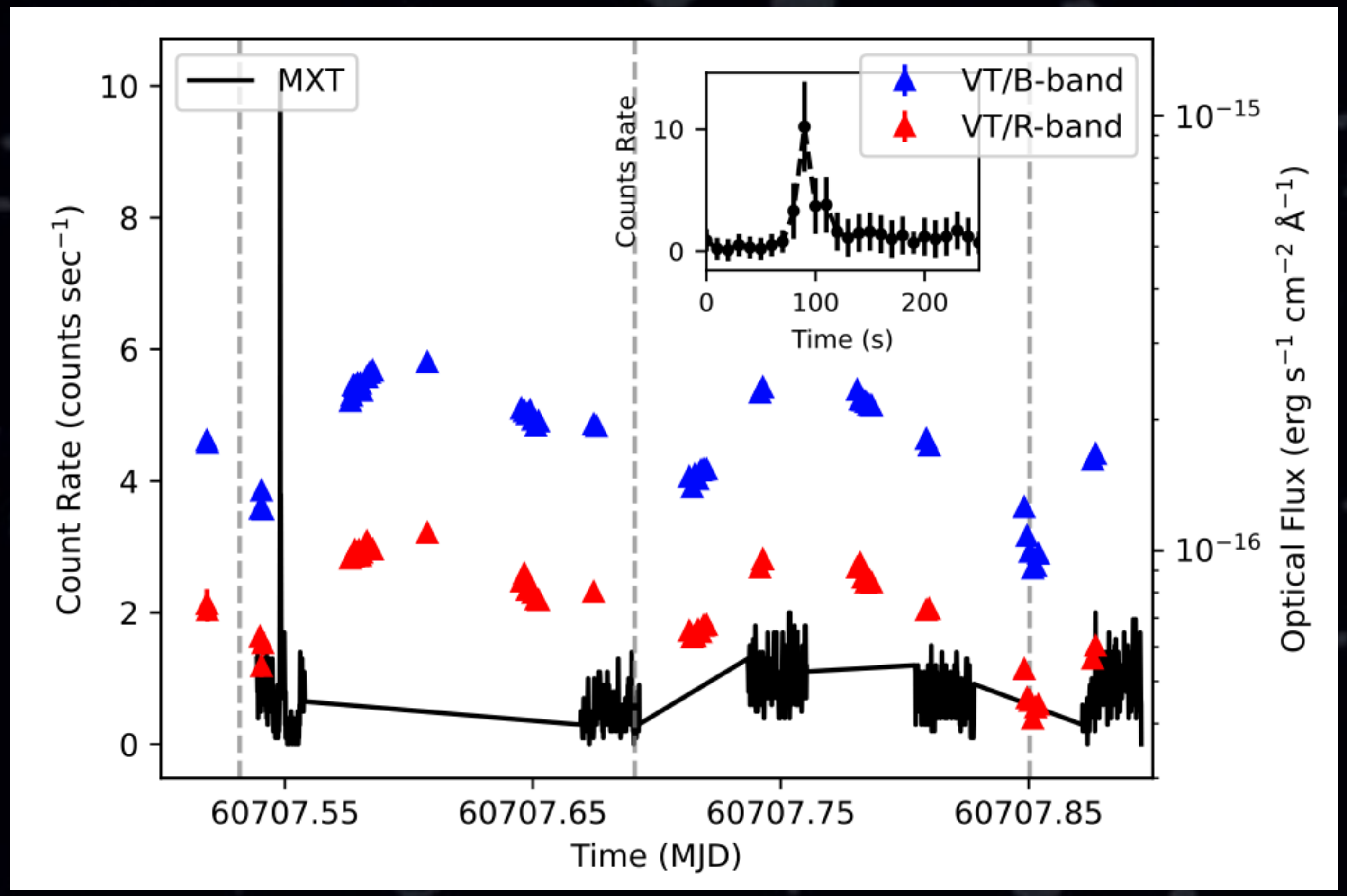
Fast optical variability of the TeV blazar PKS 1725+123 (S. Liu et al.)



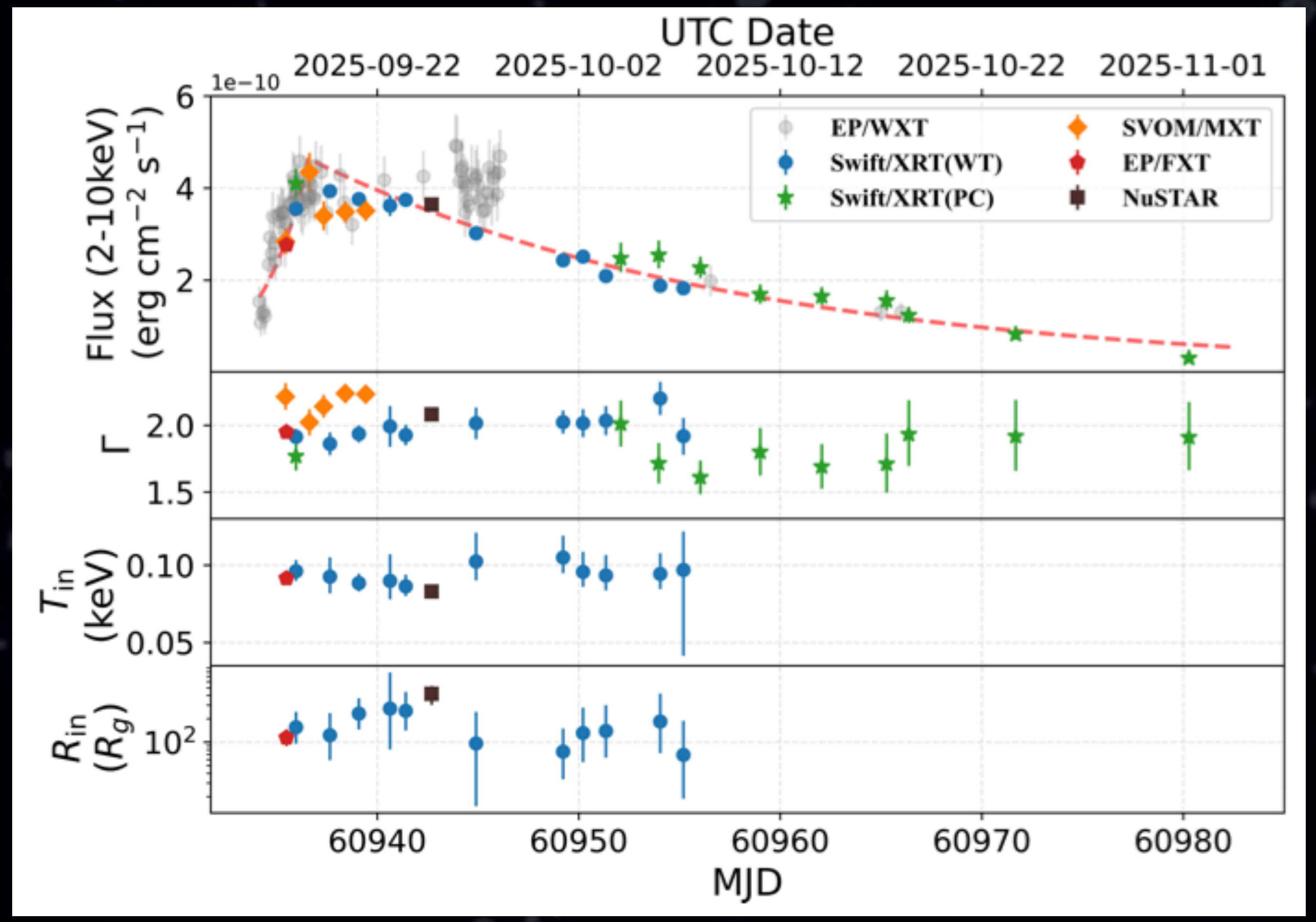
Chromospheric evaporation of a RS CVn (J. Wang et al.)



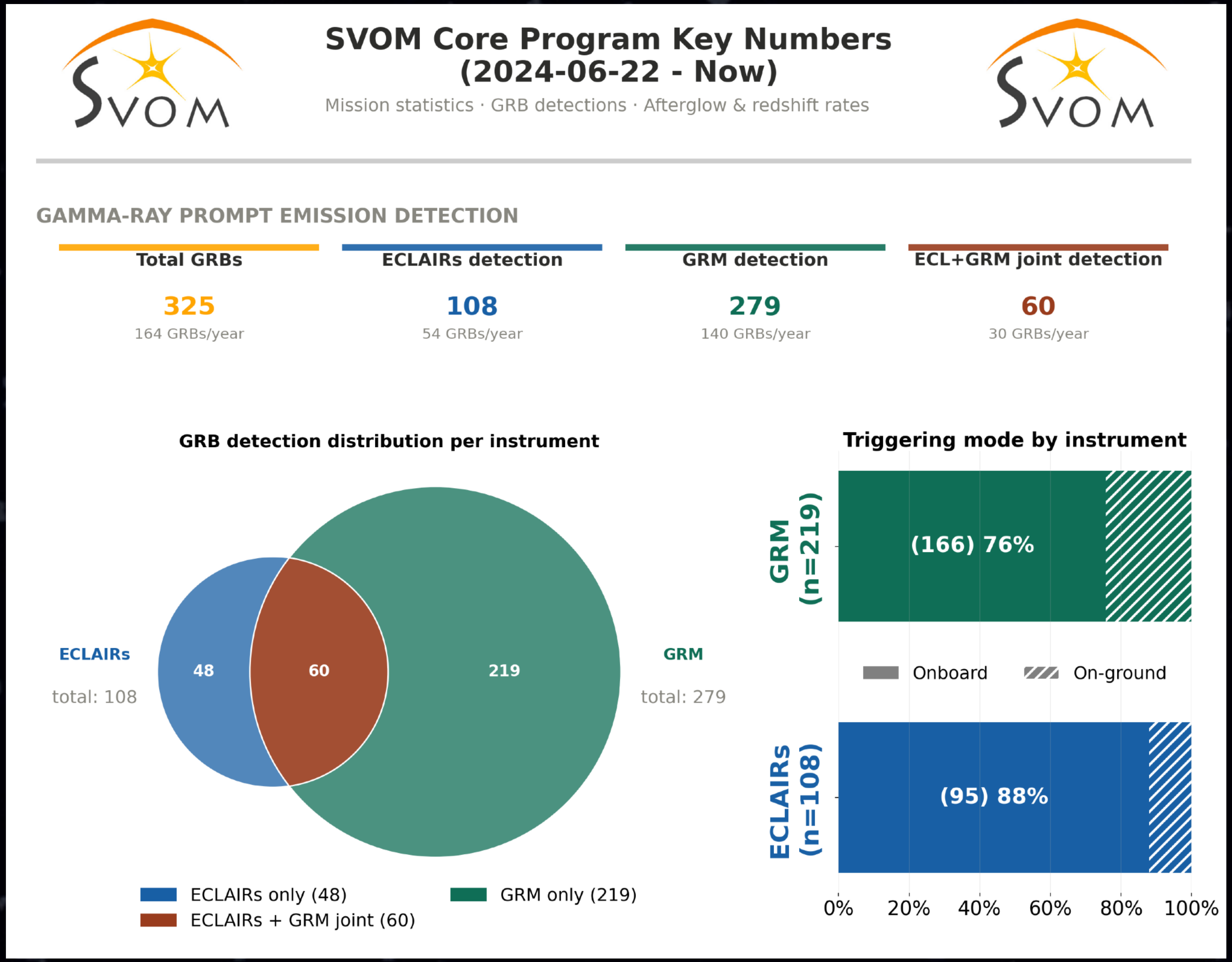
Doublet type I burst of EXO 0748 676 detected by ECLAIRs and MXT (D. Rawat et al.)

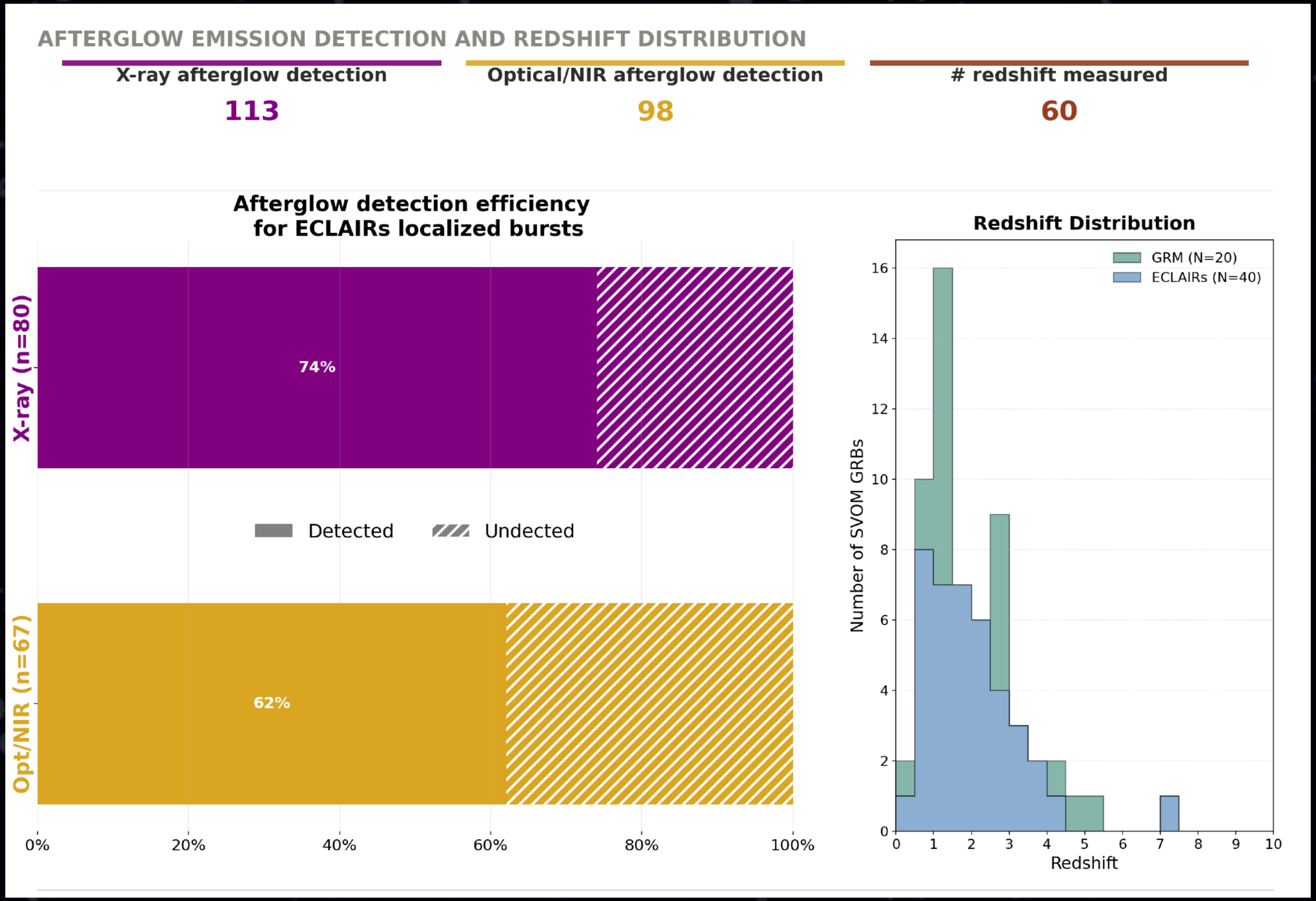


SVOM follow-up of the X-ray binary candidate EP J175257-351923 (G. Huang et al.)



Some GRB statistics (credit: D. Turpin)



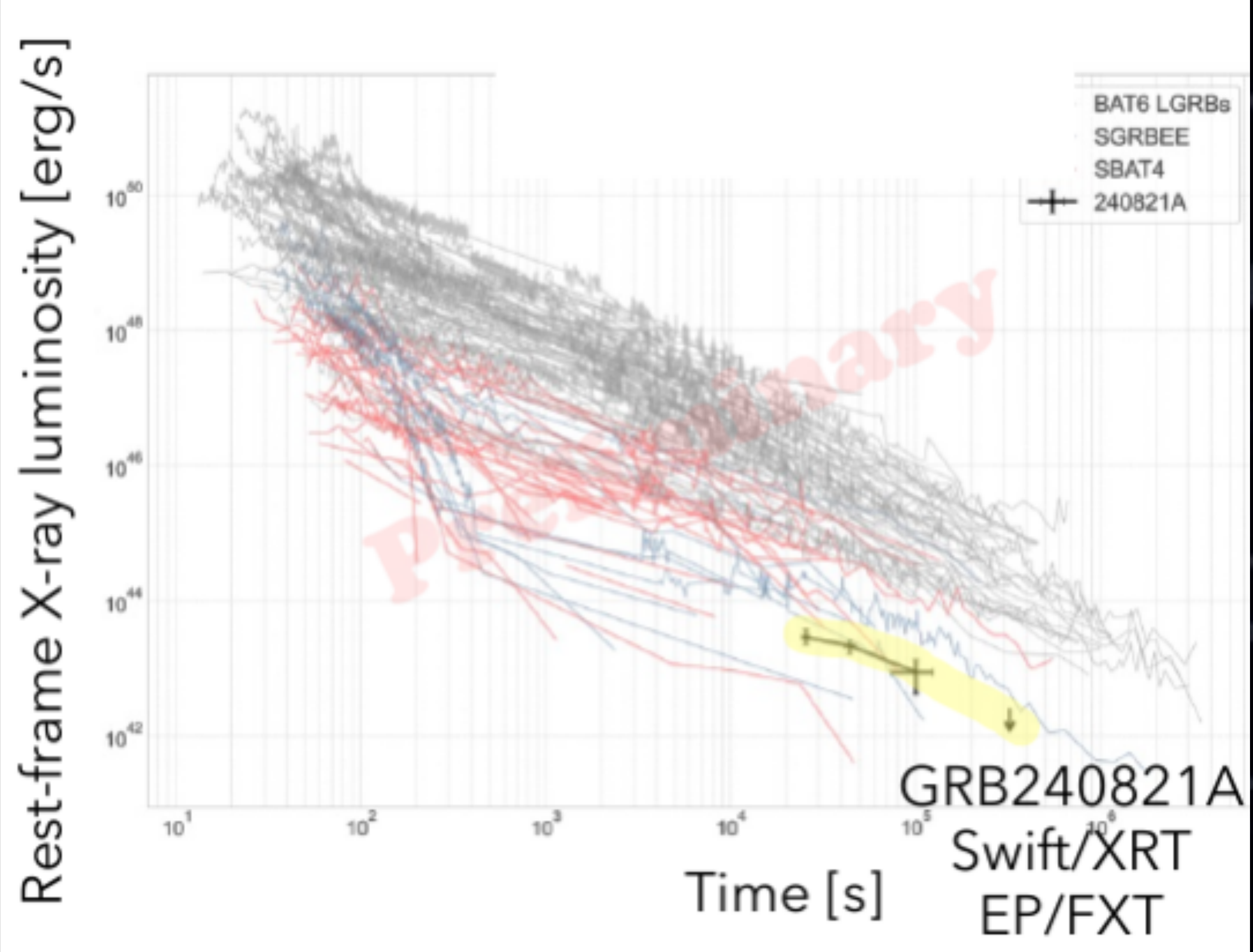


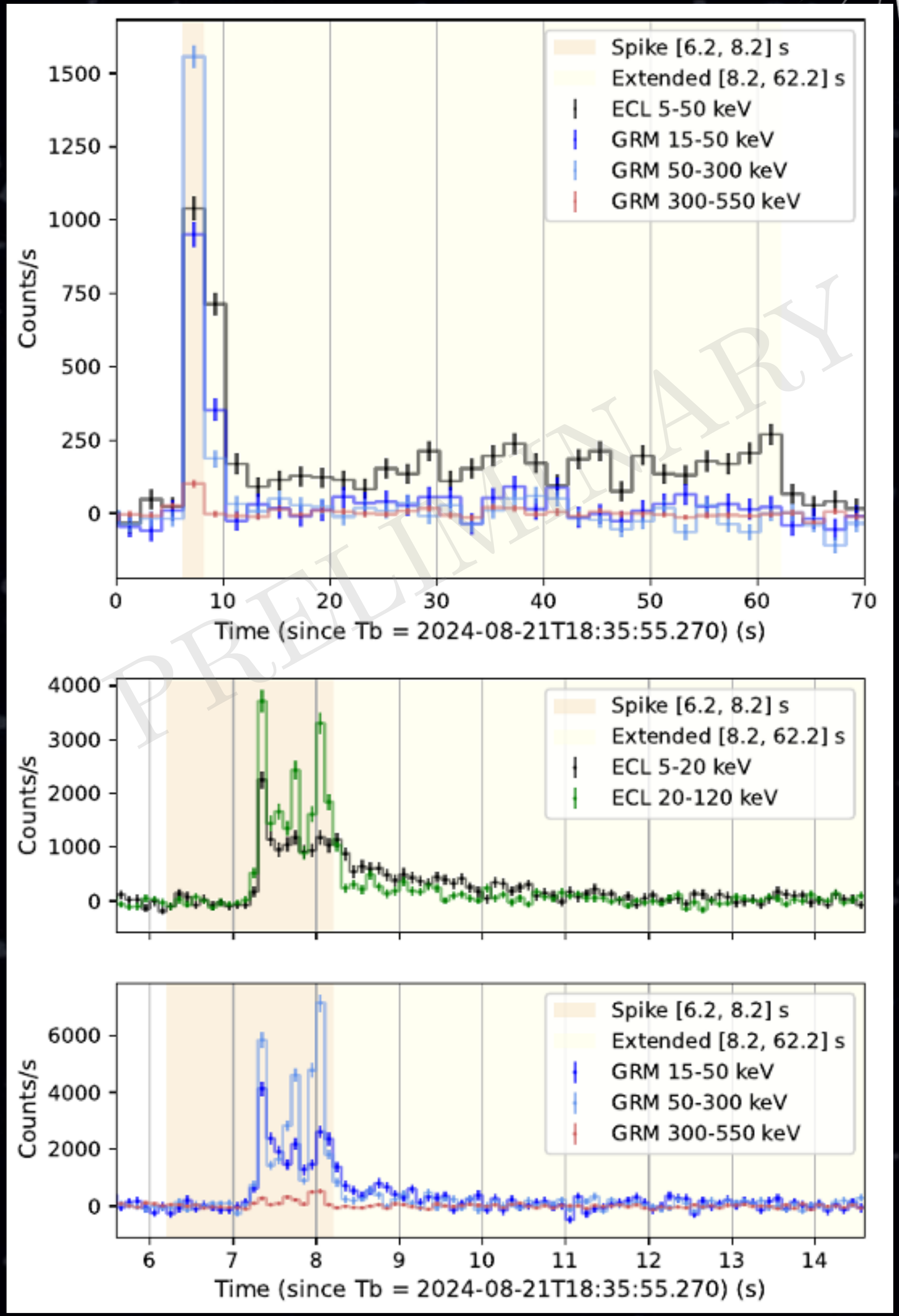
SVOM GRB science: probing the diversity of GRBs

Short GRBs (+ Extended Emission)

- Goal: contribute to build a sample of well characterized short GRBs, including the properties of the host galaxy

- GRB 240821A (z = 0.238) Daigne et al. in prep
  - First ECLAIRs + GRM joint detection (T90 ~ 50 s)
  - Initial spike (< 2 s): variable, SED peak energy E_p > 110 keV
  - Extended emission (EE): softer (E_p ~ 25 keV), still non thermal
  - Faint X-ray afterglow, but consistent with other SGRBs with EE
  - Host galaxy (GTC, VLT, Keck) properties would be unusual for LGRBs but not SGRBs



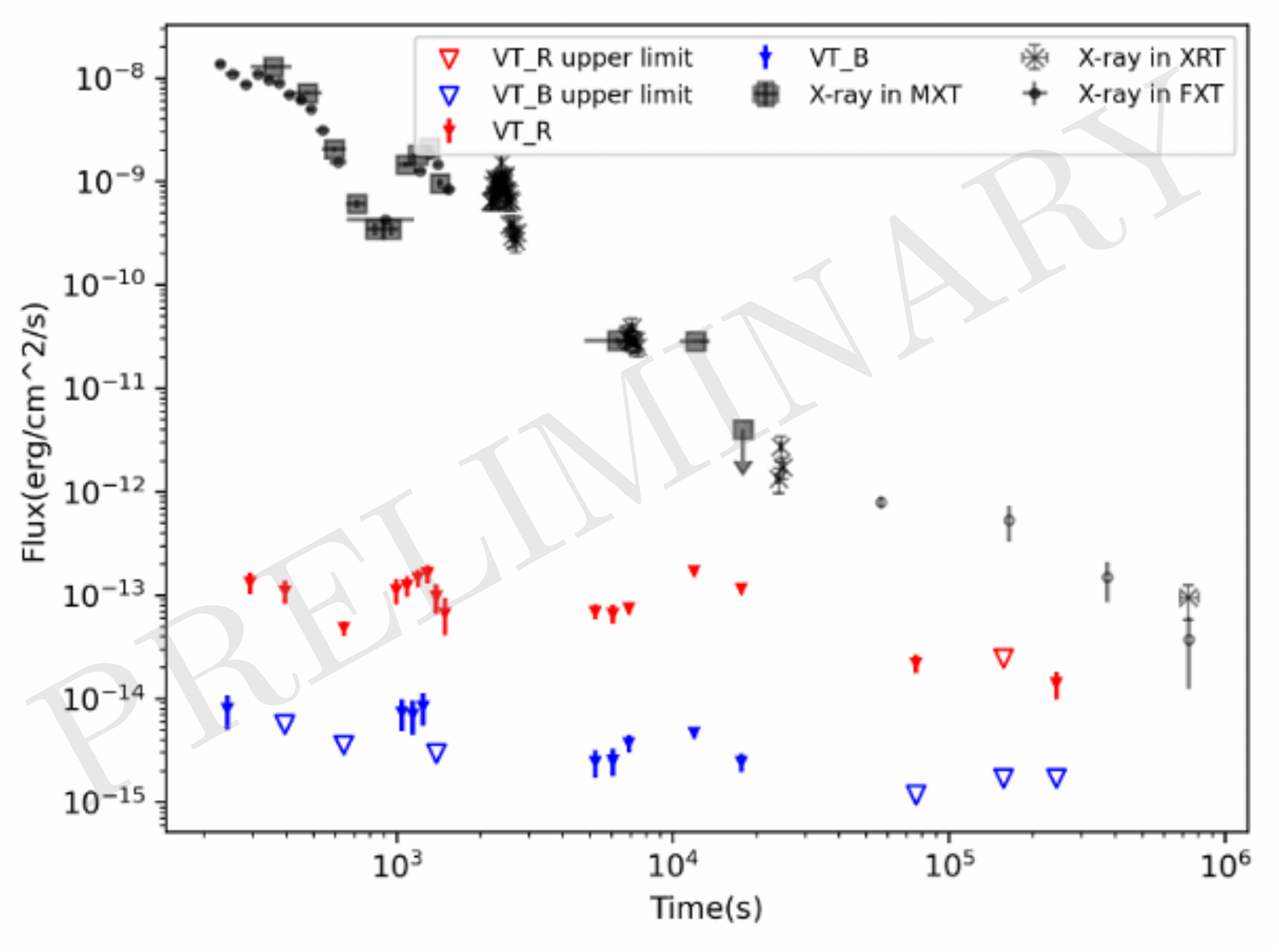


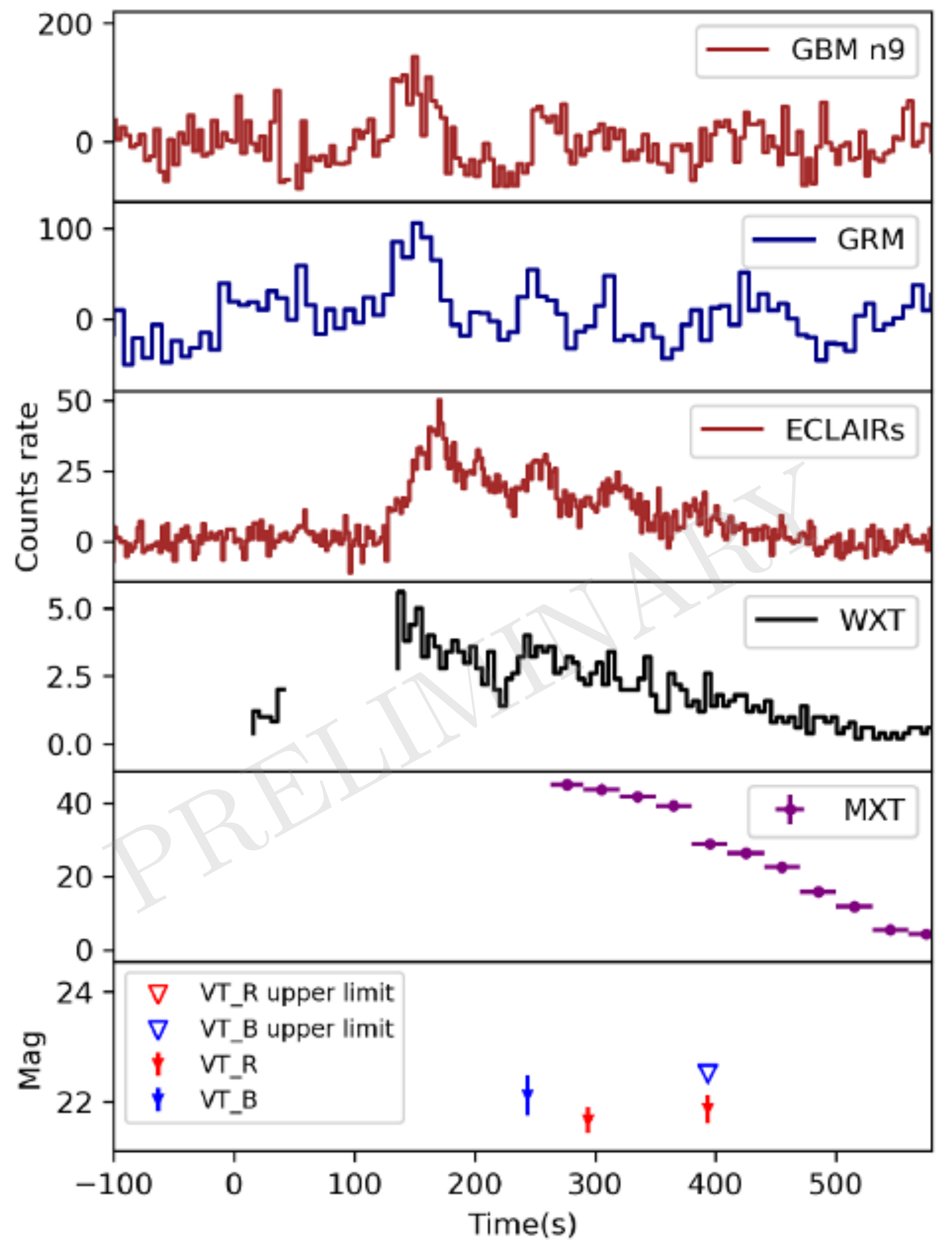
SVOM GRB science: probing the diversity of GRBs

Long GRBs

- Goal: contribute to build a well sampled multi-wavelength coverage of the prompt and afterglow phases with a high fraction of redshift determination

- GRB 241217A (z = 1.879) Brunet et al. to be submitted
  - Very long (> 500 s) GRB detected by *Fermi*, SVOM and Einstein Probe (EP)
  - MXT & VT: end of the prompt emission, and transition to the afterglow phase
  - Peculiar visible afterglow: shallow phase until ~10 ks, with possible flares
  - Not a standard scenario: late activity in a **low-density environment**?



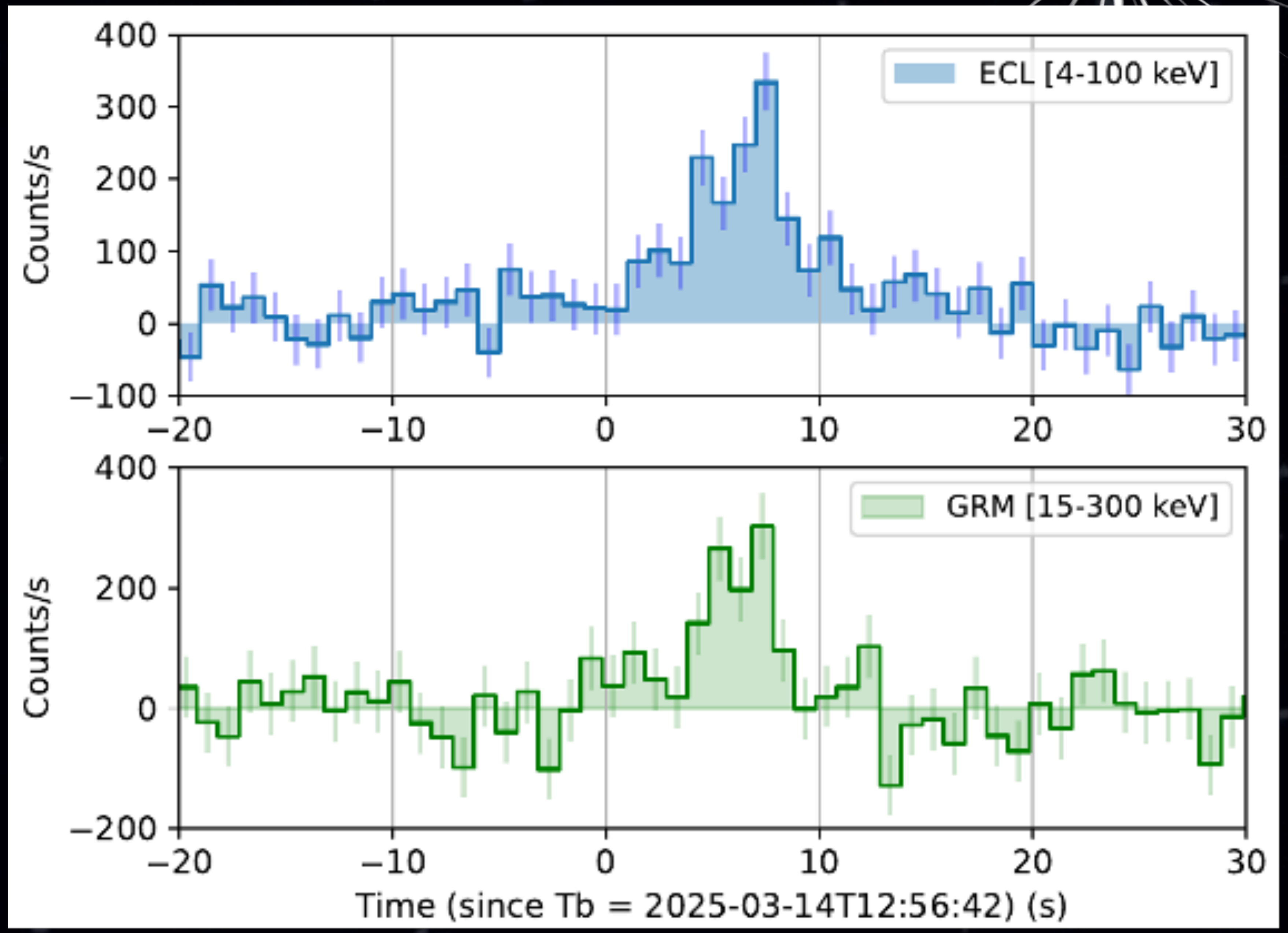


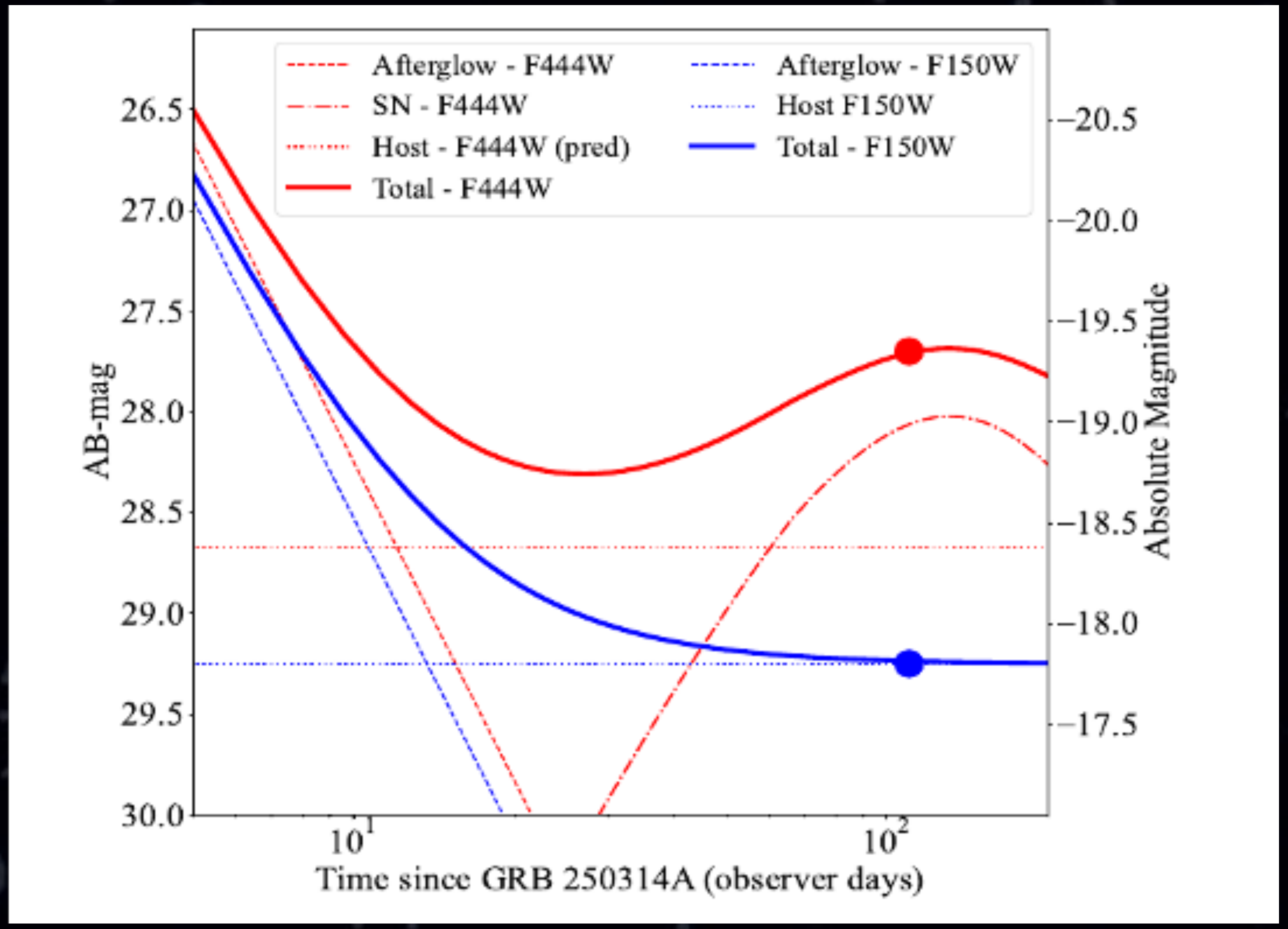
SVOM GRB science: probing the diversity of GRBs

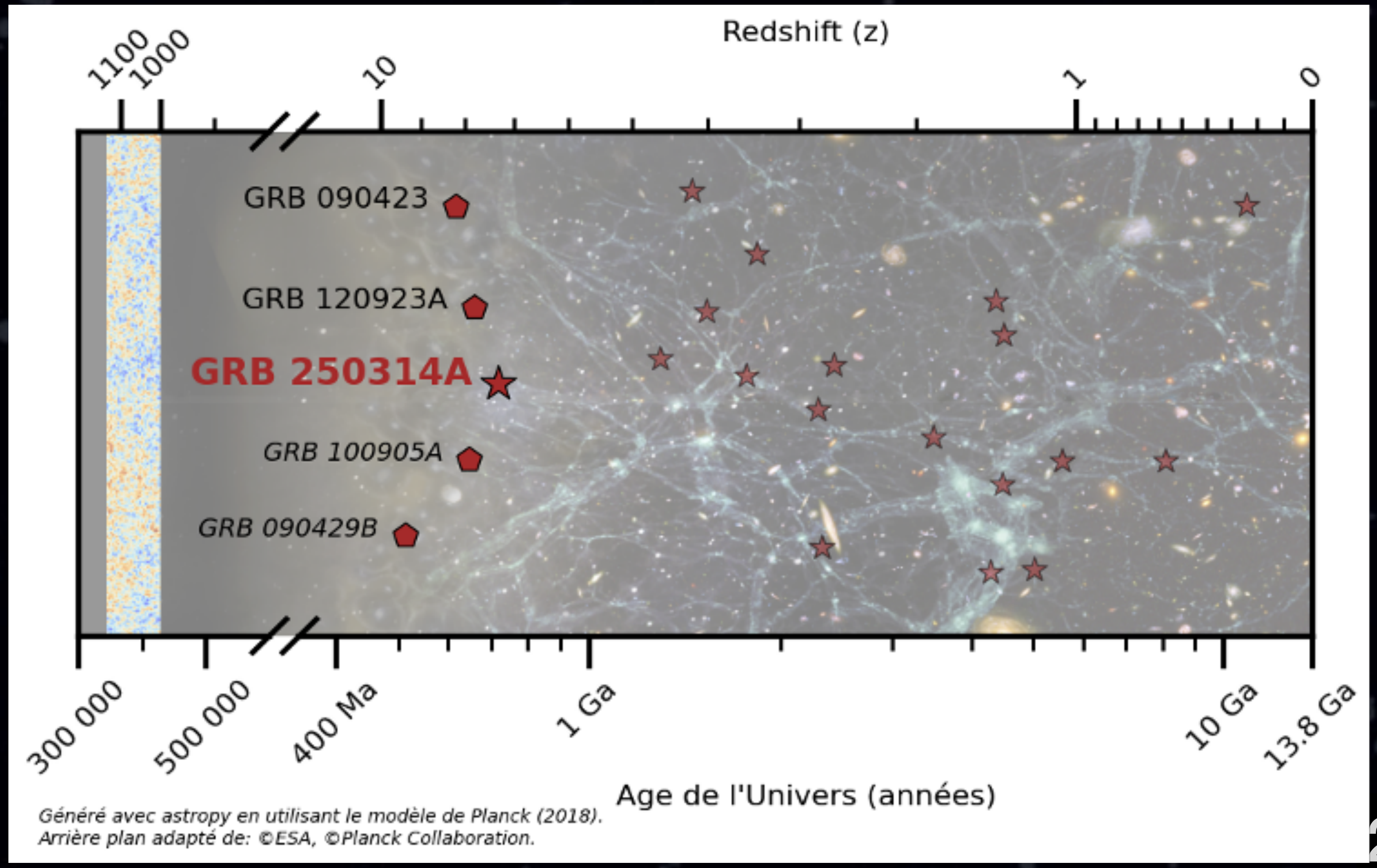
High-z GRBs

- Goal: catch high-redshift GRBs to probe the distant Universe
- GRB 250314A at **z ~ 7.3** (~730 Myr after the Big Bang)
  - Detected by ECLAIRs and GRM (T90 ~ 10 s)
  - MXT/VT quick follow-up (from T0+180s): no detection
  - X-ray afterglow detection and confirmation by *Swift*-XRT & EP-FXT
  - NIR afterglow discovered by NOT (T0+12.3h)
  - VLT/X-shooter T0+16.5h → spectroscopic z
  - JWST observations at T0+110d are compatible with the presence of a SN similar to local GRB-SN (SN 1998bw). This would be the **farthest SN ever detected**
    → Suggest collapse mechanism of massive stars may be the same in the early Universe as in our local Universe

Cordier et al. 2025
Levan et al. 2025



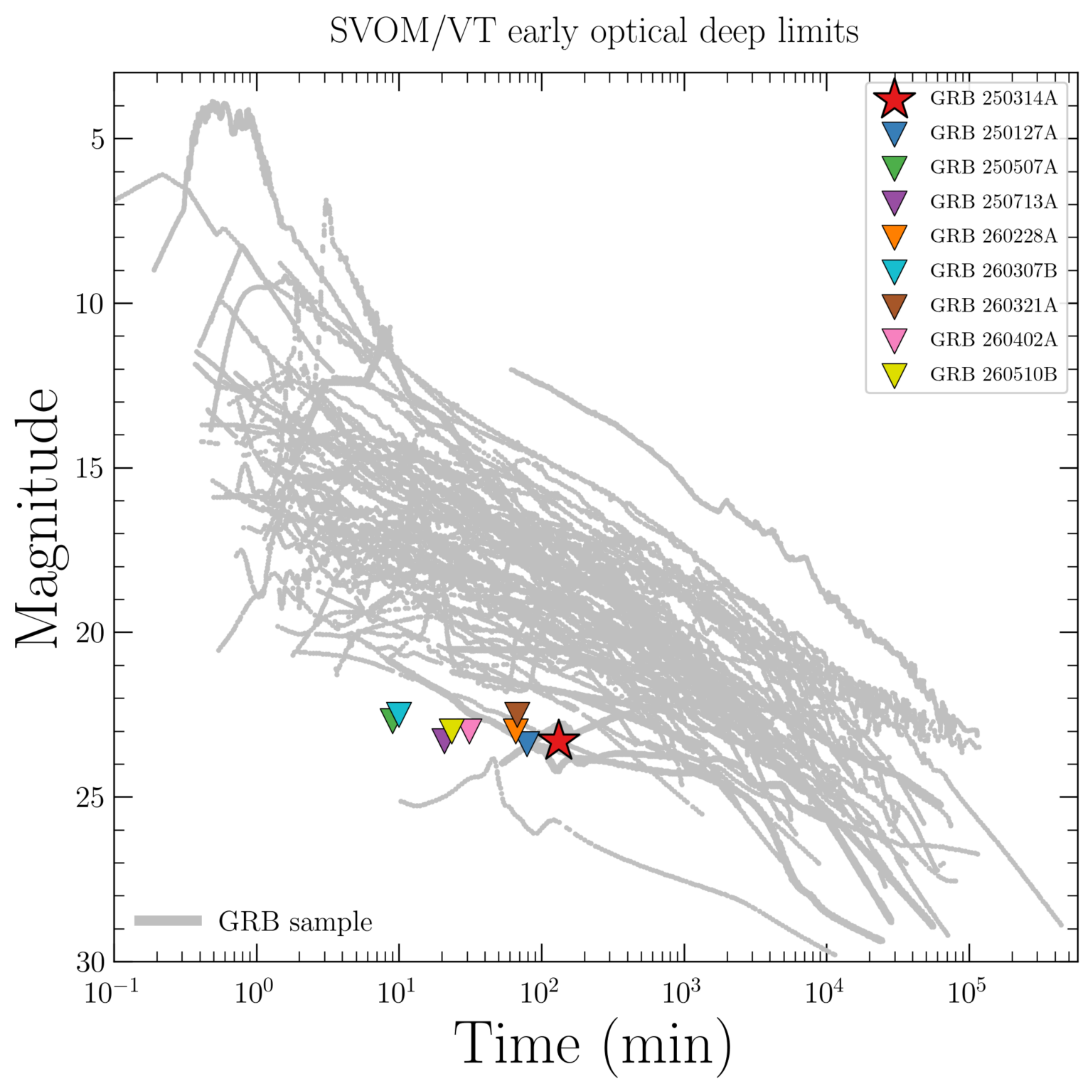




SVOM GRB science: probing the diversity of GRBs

High-z GRBs

- Other potential high-z GRBs missed?
- Could also be dusty GRBs or intrinsically faint
- The arrival of CAGIRE on COLIBRÍ and SOXS should help by providing **NIR coverage**



SVOM GRB science: probing the diversity of GRBs

Soft GRBs

- Goal: bring a complete physical interpretation of the poorly known population of very soft X-ray burst

- Population discovered by Beppo-SAX and HETE-2, also well explored by Einstein Probe
  - Classification: X-Ray Rich GRBs (XRRs) or X-Ray Flashes (XRFs)
  - Soft and under-luminous, faint X-ray afterglows with single decay
  - Sample of well-characterized events is limited
  - SVOM classification project underway: Godet et al. in prep.

- Physical mechanism at play?
  - Shock breakout emission?
  - geometry effect → off-axis jet?
  - Low Γ jets?
  - High-z redshift effect?

SVOM GRB science: probing the diversity of GRBs

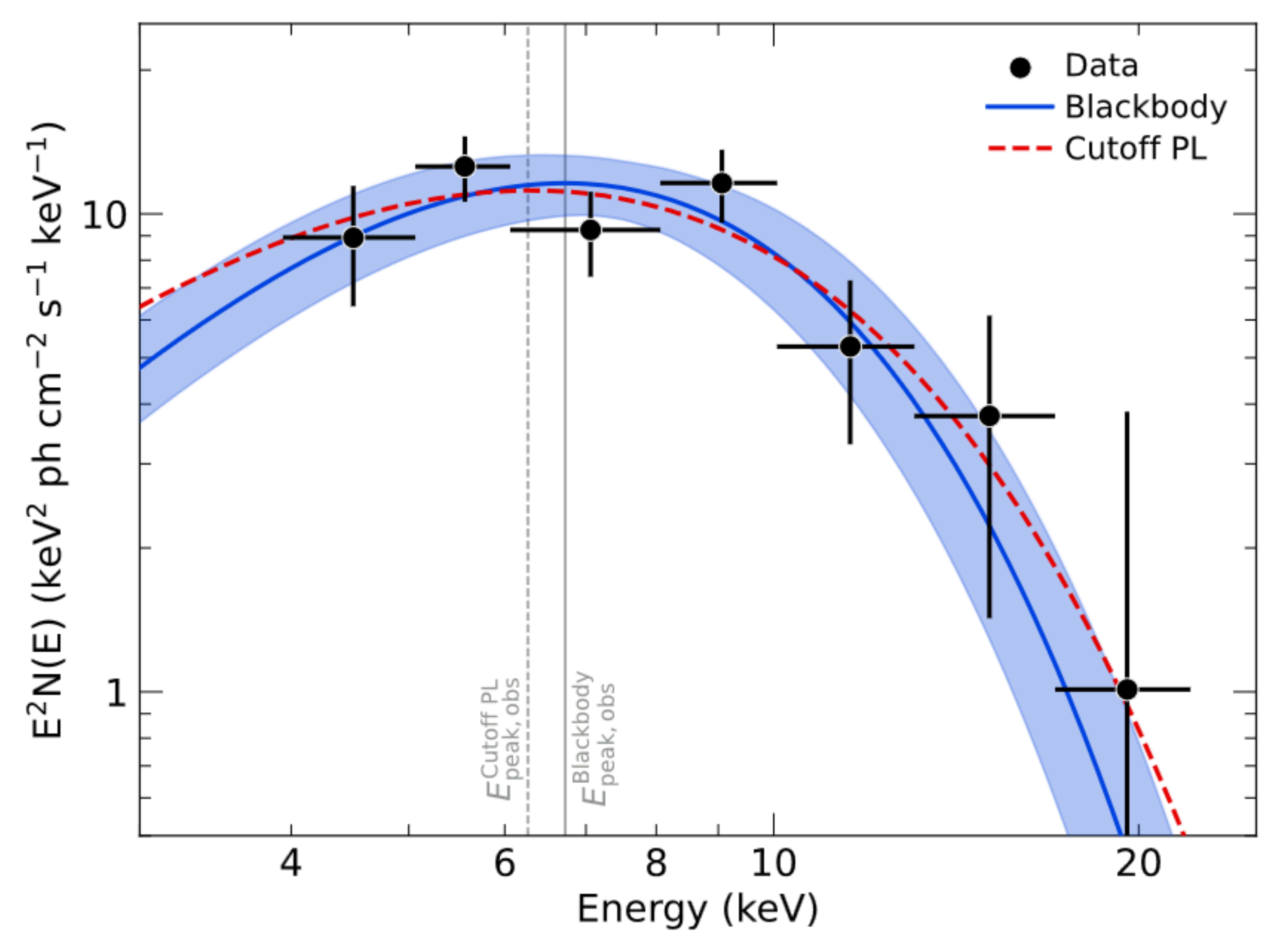
Soft GRBs

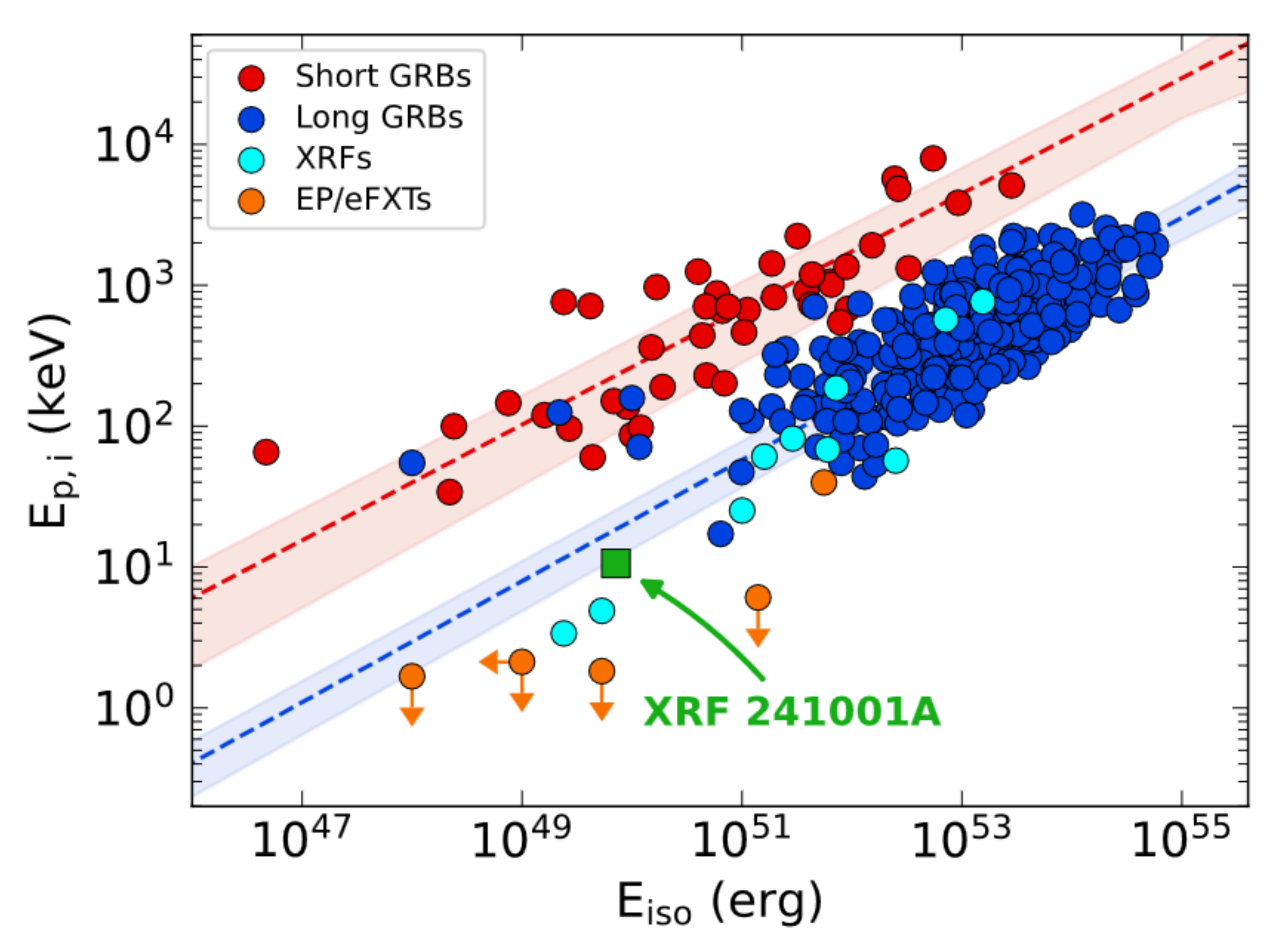
For the case of GRB 241001A ($z = 0.573$):

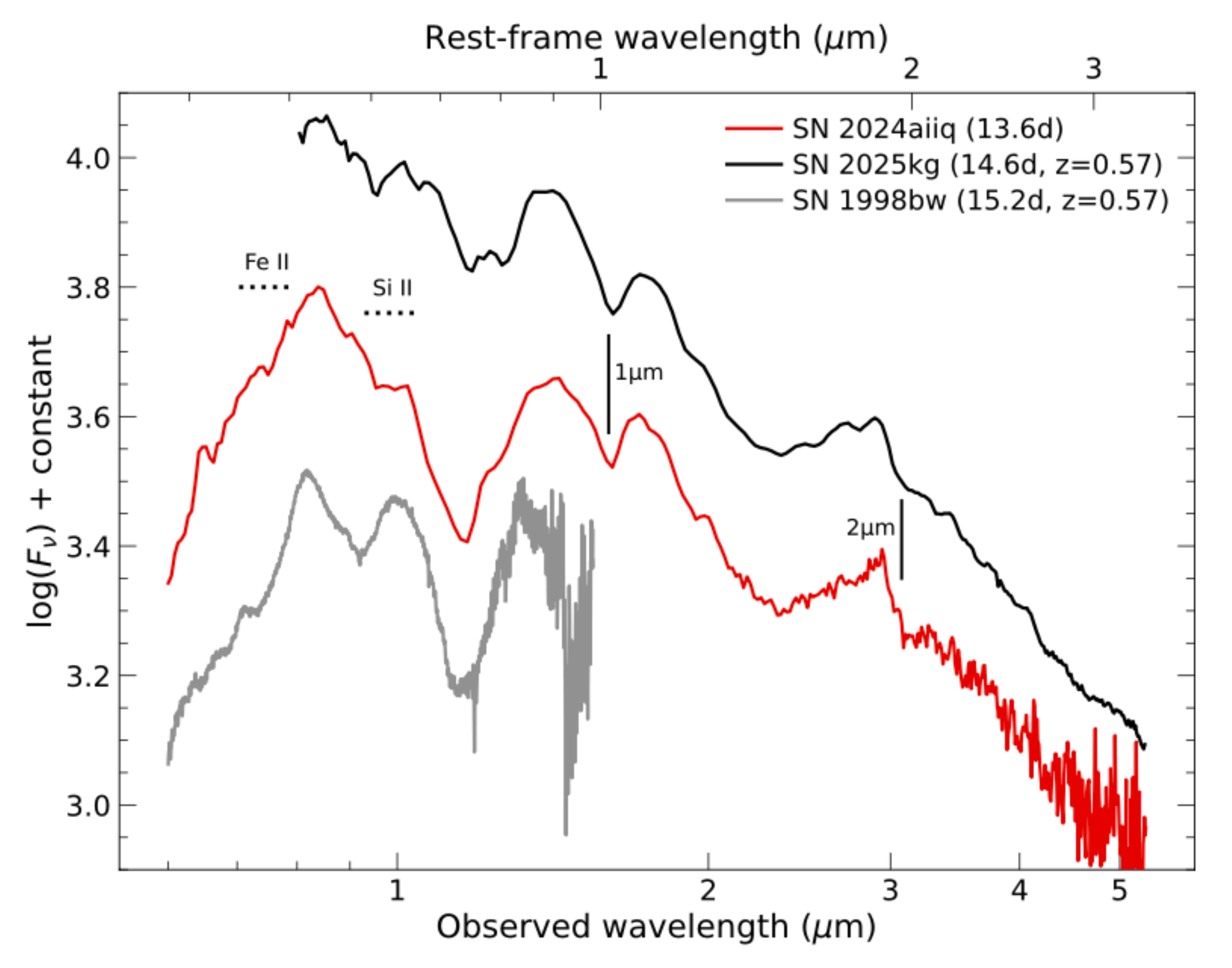
- Weak relativistic on-axis jet
- Soft nature is intrinsic to the event
- SN Ic-BL detected by JWST confirms a collapsar

→ Low-luminosity tail of the classical GRB population?

Schneider et al. submitted A&A



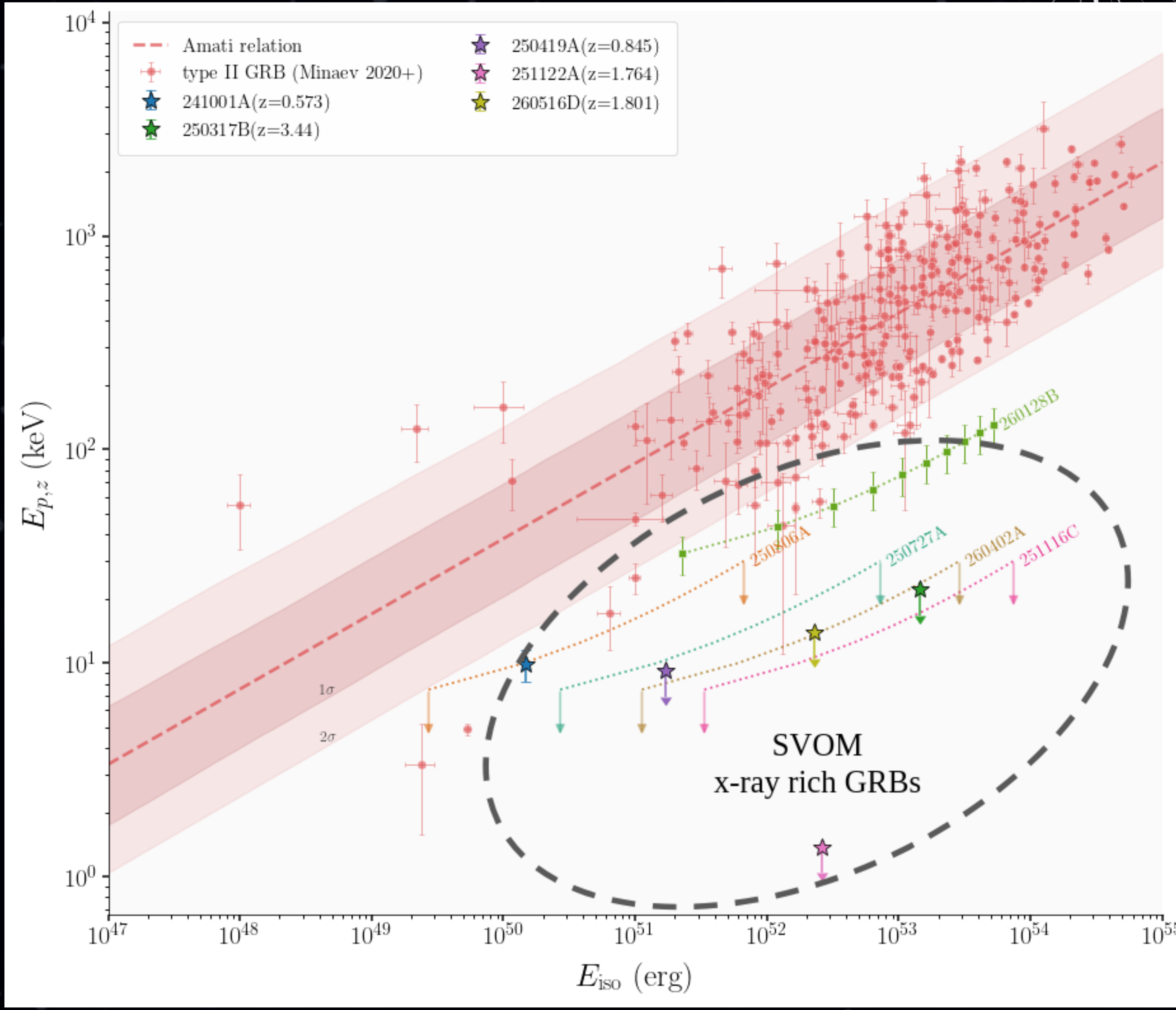




SVOM GRB science: probing the diversity of GRBs

Soft GRBs

- Many more examples… e.g. GRB 251122A Lin et al. in prep.
- SVOM is populating a new region of the GRB parameter space!
- See also talk by D. Turpin



Credit: D. Turpin

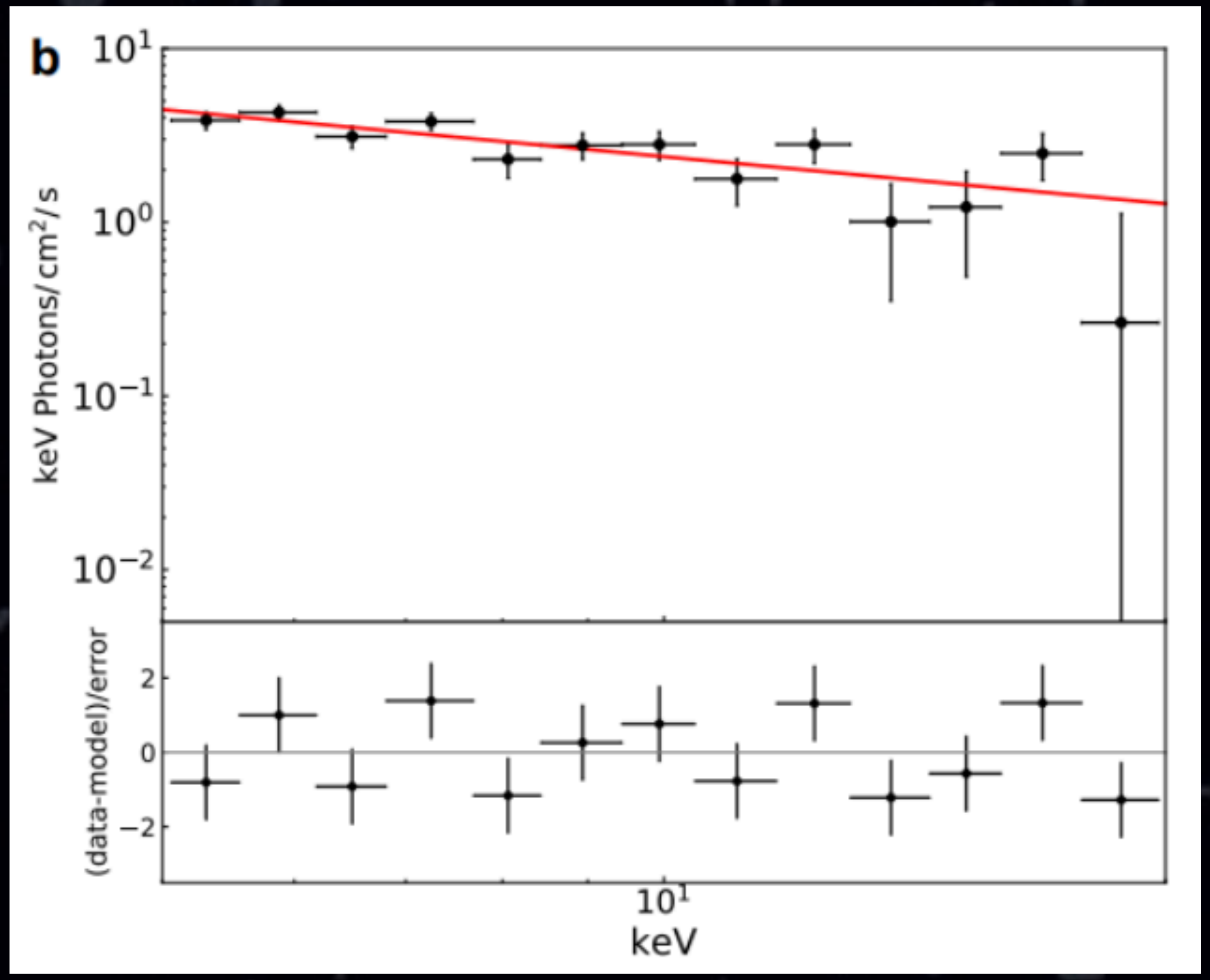
SVOM GRB science: probing the diversity of GRBs

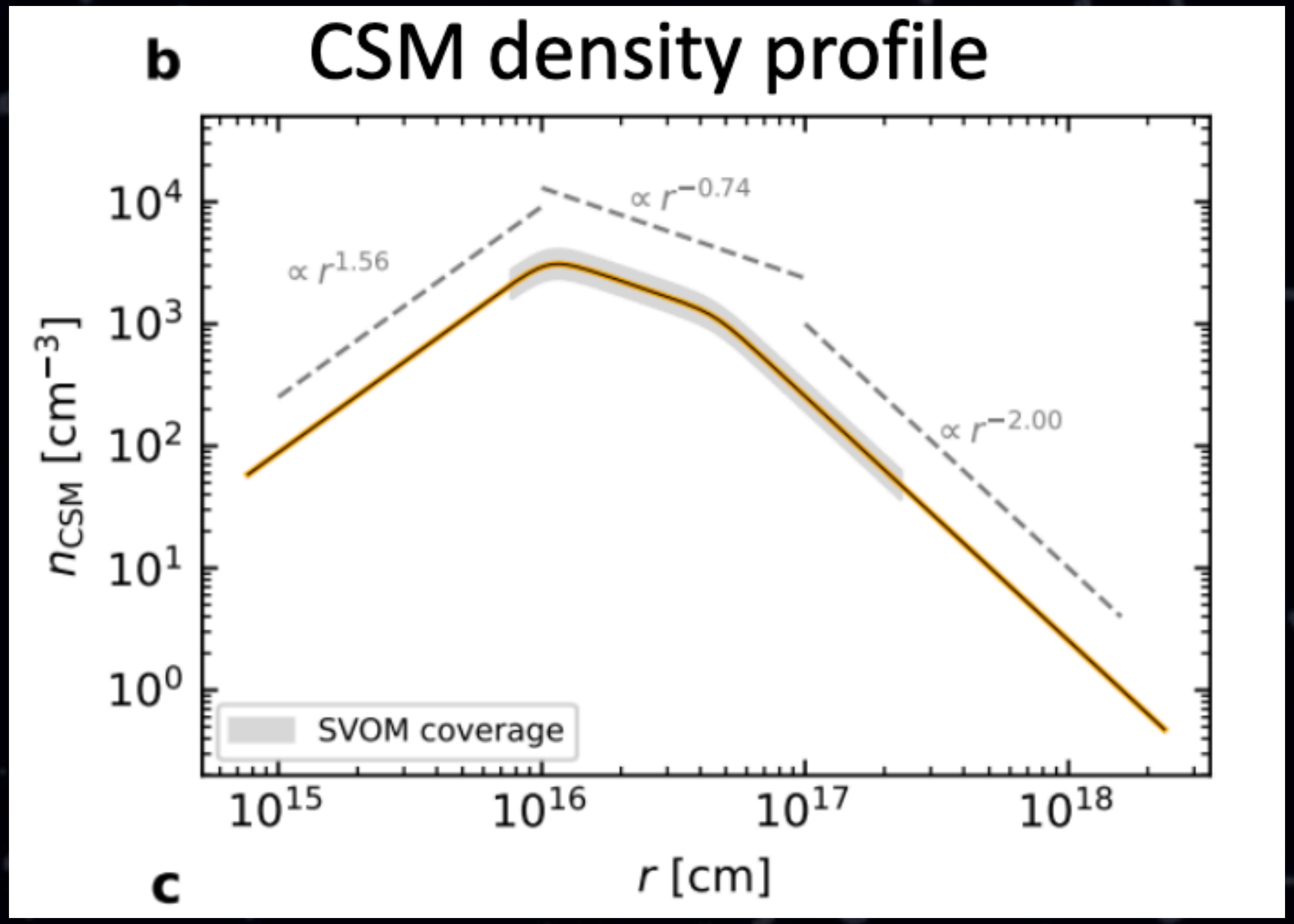
Soft GRBs

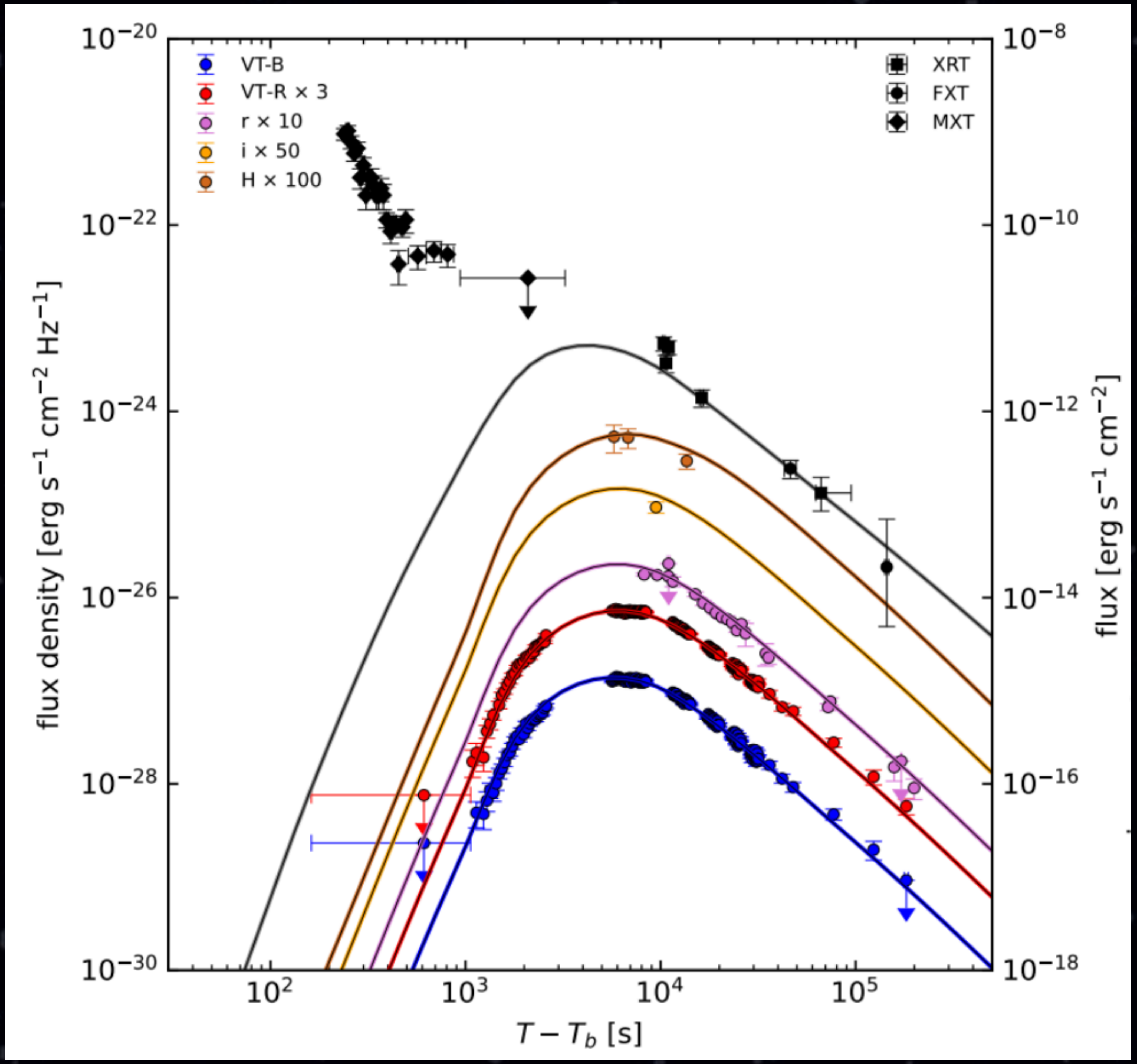
For the case of GRB 250317B ($z = 3.448$):

- $E_p < 5$ keV
- Highest redshift X-Ray Flash (XRF)
- On-axis jet with low-Γ (~20) but normal energetics (~1e54 erg)
  → Dirty fireball?
- **Structured CSM** (probes mass-loss history of the progenitor)

Zhao et al. to be submitted to NA

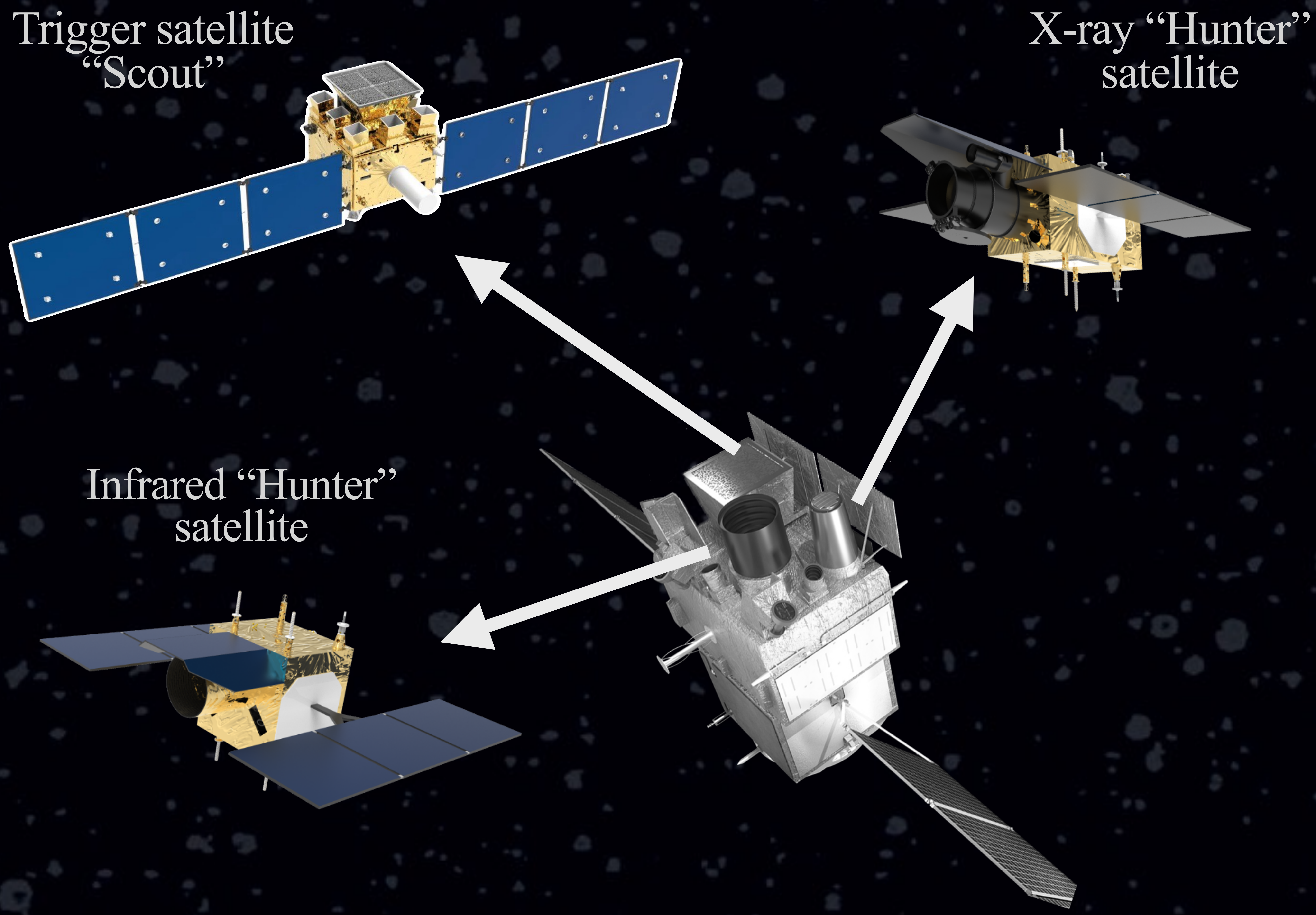






Next step after SVOM: CATCH

(Credit: S. Schanne)



Principle:

- Constellation of mini-satellites (300-500 kg)
- Chinese Recurrent platform (IAMC-CAS)
- Agile development

CATCH-PM: "Precursor Mission"

- Const. Demonstrator
- Reuse of spare parts
- Launch ~2030
- Joint operations with SVOM & EP desired

Conclusion

- A 4 keV low energy band a clear impact to better explore
  - The softest GRBs and the XRR/XRF population
- A full spectral coverage of the burst's emission from 4 keV - 5 MeV
  - Detection of all types: ~76% LGRBs, ~15% SGRBs (+EE), ~9% XRRs/XRFs (not yet based on a systematic classification)
  - First catalogs are in preparation GRM: Tan et al. in prep.; ECL: Godet, Maiolino, Bernardini et al. in prep.
- Dedicated follow-up instruments (space and ground-based) enable:
  - Several well-characterized events during the prompt & early/late afterglow phases
  - Prompt-to-afterglow transition for some bursts
  - Several cases on non detection in VT: dark or high-z bursts?
    Prompt systematic NIR Follow-up is still missing, but CAGIRE and SOXS will help
- A pointing strategy optimized to coordinate fast follow-up observations
  - Already a high rate of optical afterglow detection and redshift measurement, still increasing
- Already fruitful Collaboration with other missions and groups
  - Efficient ToO links between SVOM, Einstein Probe and *Swift* (fingers crossed for a successful boost!)
  - ESO/VLT (Stargate collaboration), GTC and NOT
- A collaboration open to exchange of data on specific science projects
  - SVOM is open to jointly publish its data as lead collaboration or as partner
  - All critical SVOM information is publicly available through GCNs
  - SVOM is open for ToOs from the community, provided that one co-I is involved

SVOM Special Issue in press (RAA)

> 20 ongoing single GRB projects

4 already published

> 2000 GCN circulars related to SVOM