



Einstein Probe:

exploring the dynamic X-ray universe

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ESAC, ESA

on behalf of the Einstein Probe consortium

Wide-field X-ray Telescope

WXT (12 modules)



Lobster-eye MPO + CMOS
FoV: > 3,600 sq deg (1.1 sr)
Band: 0.5 – 4 keV
Angular resolution: ~ 5' (FWHM)
Sensitivity: ~1mCrab @1ks

Follow-up X-ray Telescope

FXT (2 units)



Wolter-1 + pn-CCD (eROSITA)
FoV: ~1 deg
Band: 0.3 -10keV
Angular resolution: 24'' (HPD, on-axis)
Effe. area: ~300 cm² @1keV (x 2 units)



Spacecraft



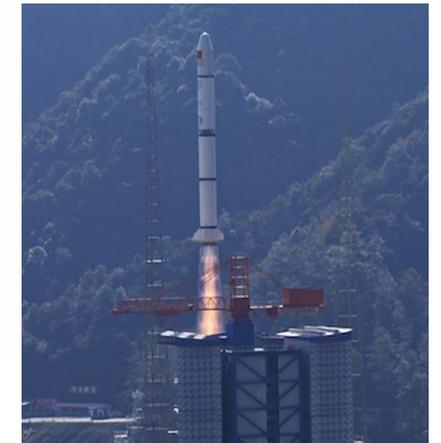
On-board data processing
Quick slew & autonomous follow-up

Telemetry

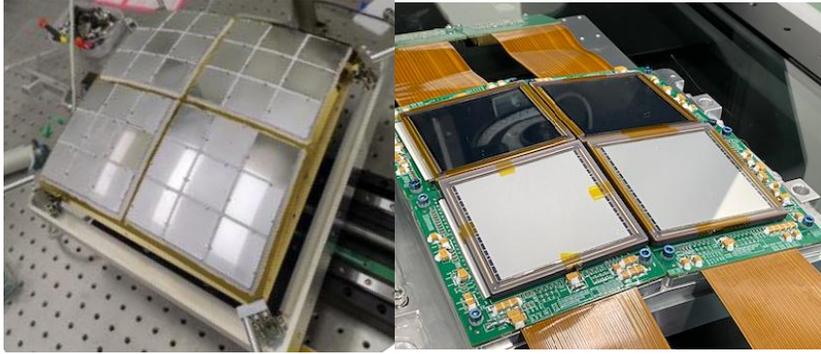


X/S-band (several hours)
BD (down/up-link; minutes)
VHF (down-link; minutes)

launched 2024 Jan 9
@Xichang, China



Instruments & spacecraft



WXT mirror & CMOS detectors (1 module)



WXT chief designer
Xiaojin Sun (SITP/CAS)



Lead of LE mirrors
Chen Zhang (NAO/CAS)



FXT FM built at IHEP/CAS



PI: Yong Chen
(IHEP/CAS)



FXT mirror assembly FM
(ESA/MediaLario/MPE)



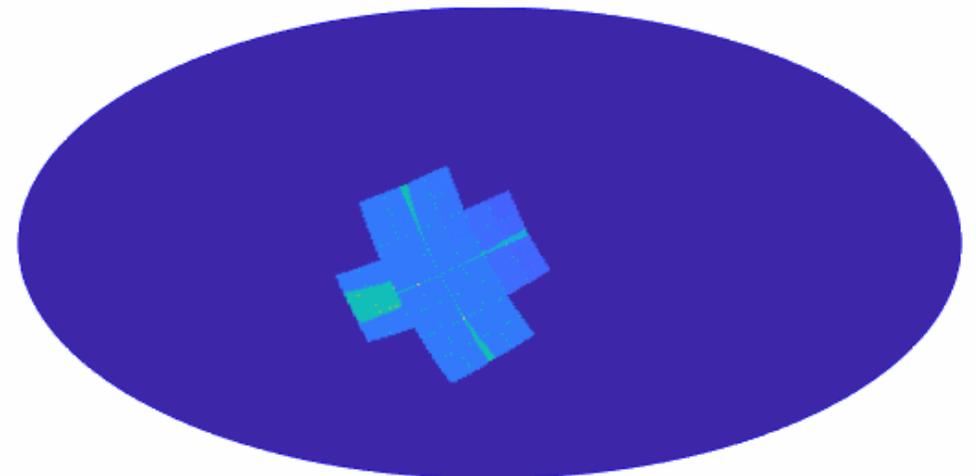
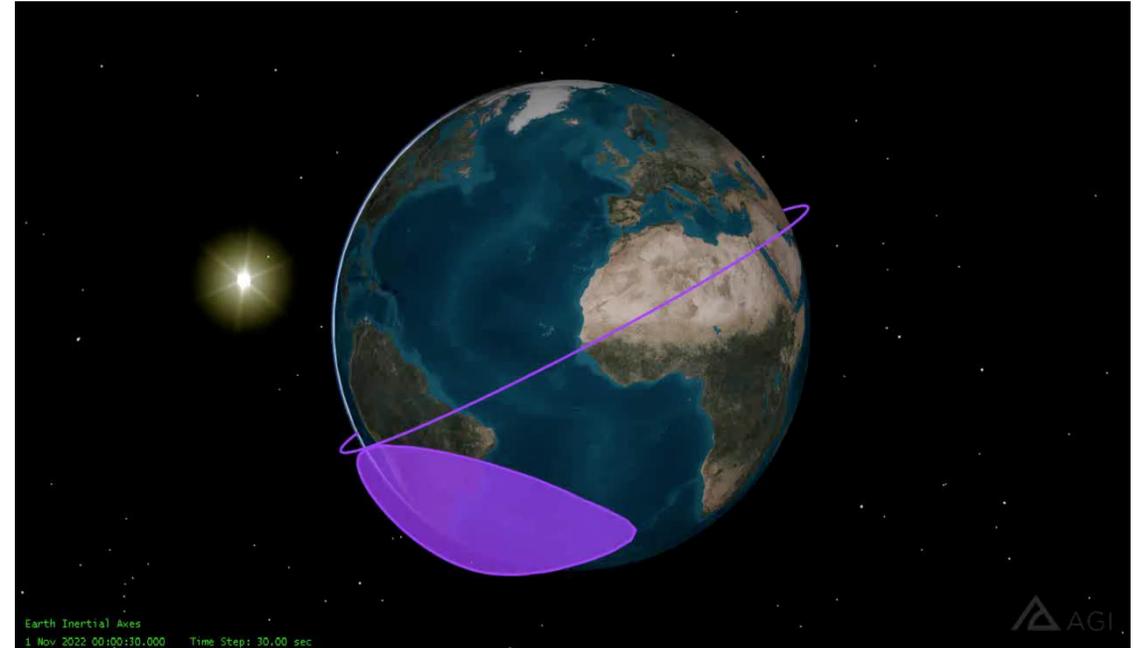
acoustic test



thermal vacuum test @ CAS

Observation modes

- ❏ Circular orbit
 - Height 592km, period 96min
 - inclination angle 29 deg.
- ❏ **Observation modes**
 - Survey (primary WXT)
 - Autonomous follow-up (FXT)
 - ToO (FXT, WXT) – quick response
- ❏ **WXT survey mode**
 - Pointing to night sky
 - 3 pointings/orbit, ~20min each
 - ~ 1/2 sky covered in 3 orbits (~ 5 hr)
 - Whole sky coverage in 1/2 year
 - FXT pointed to pre-selected targets



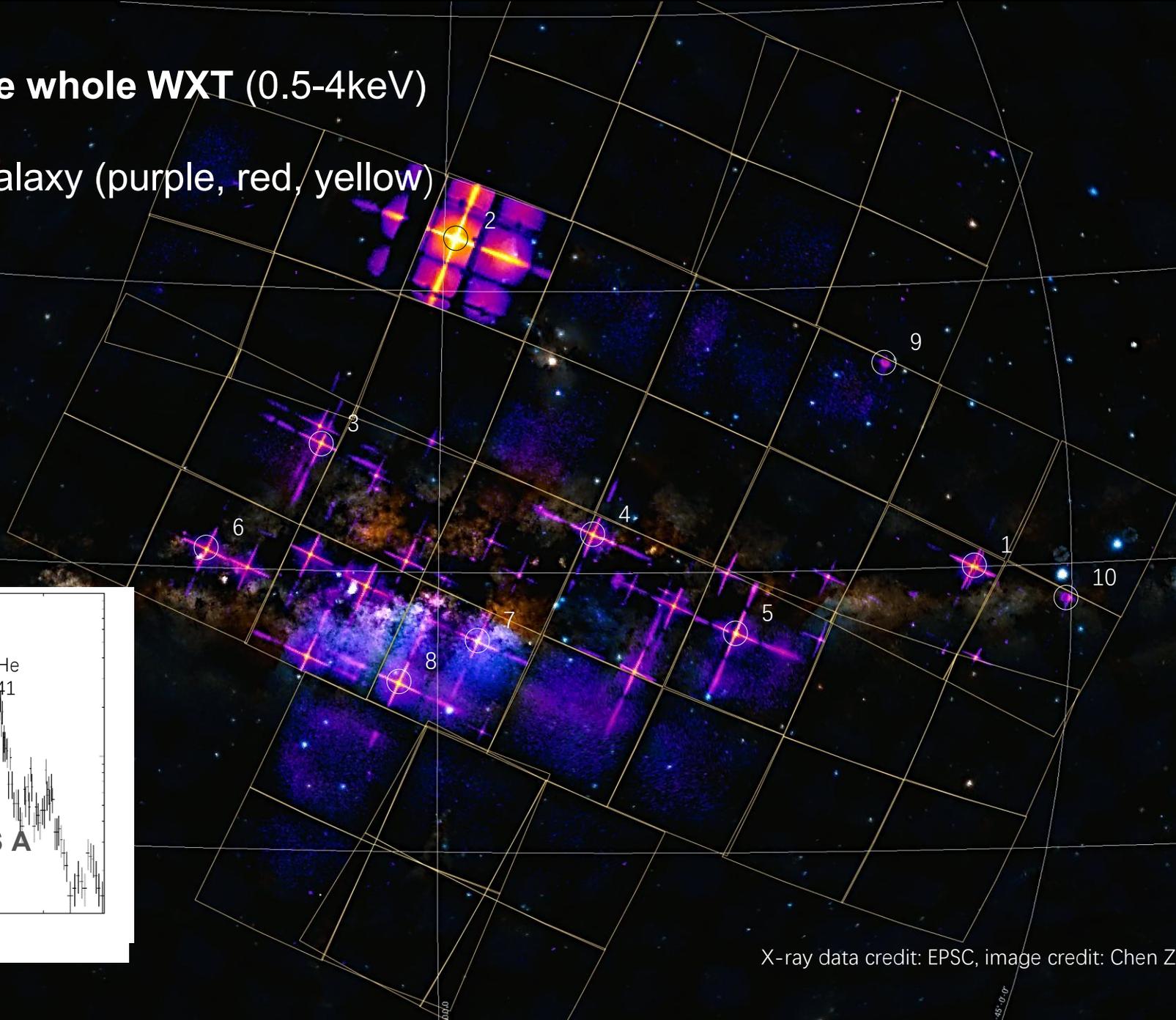
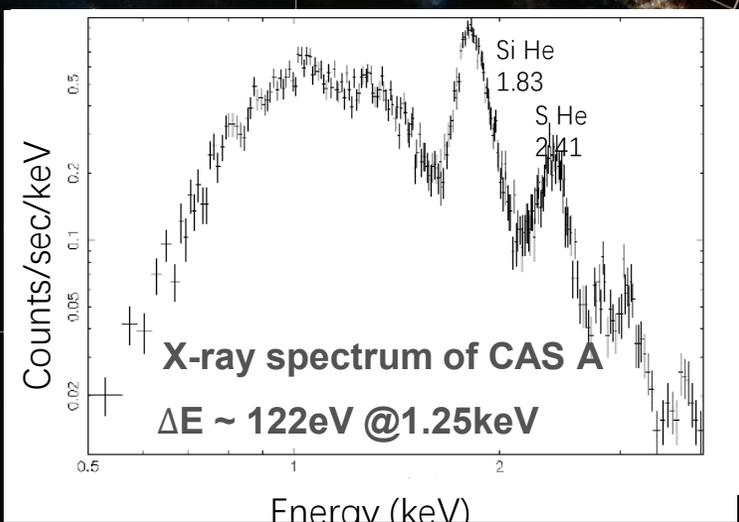
First light image of the whole WXT (0.5-4keV)

Central region of the Galaxy (purple, red, yellow)

exposure 40 kilo-seconds

WXT FoV 3850 sq. deg.

9.3°



- 1: Cir x-1 and *Swift* J151857.0-572147
- 2: Sco X-1
- 3: V2216 Oph
- 4: V1101 Sco
- 5: V821 Ara
- 6: NP Ser
- 7: V4134 Sgr
- 8: Sgr X-4
- 9: Lupus SN
- 10: SNR RCW 86

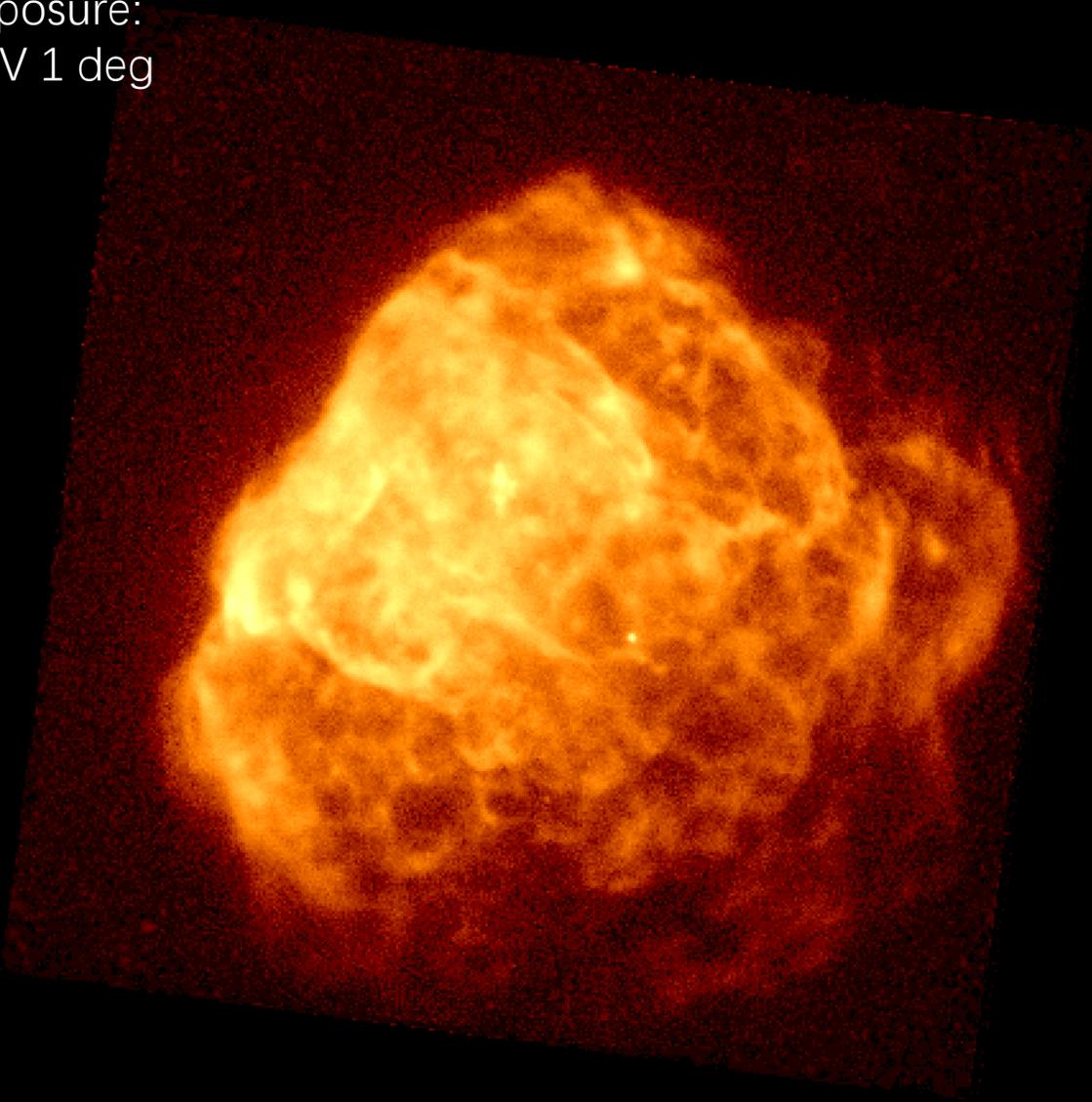
X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.

FXT X-ray First light (0.3-10 keV)

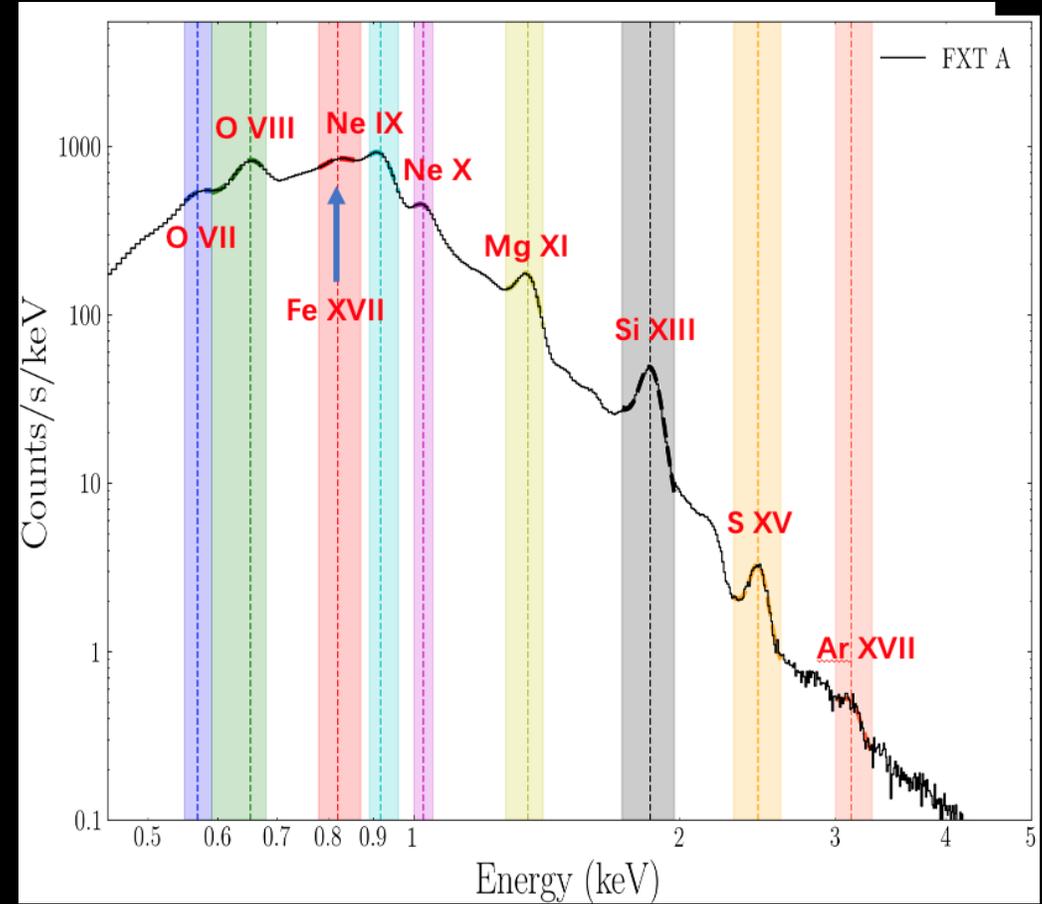
Puppis A supernova remnant (nebula)

Exposure:

FoV 1 deg



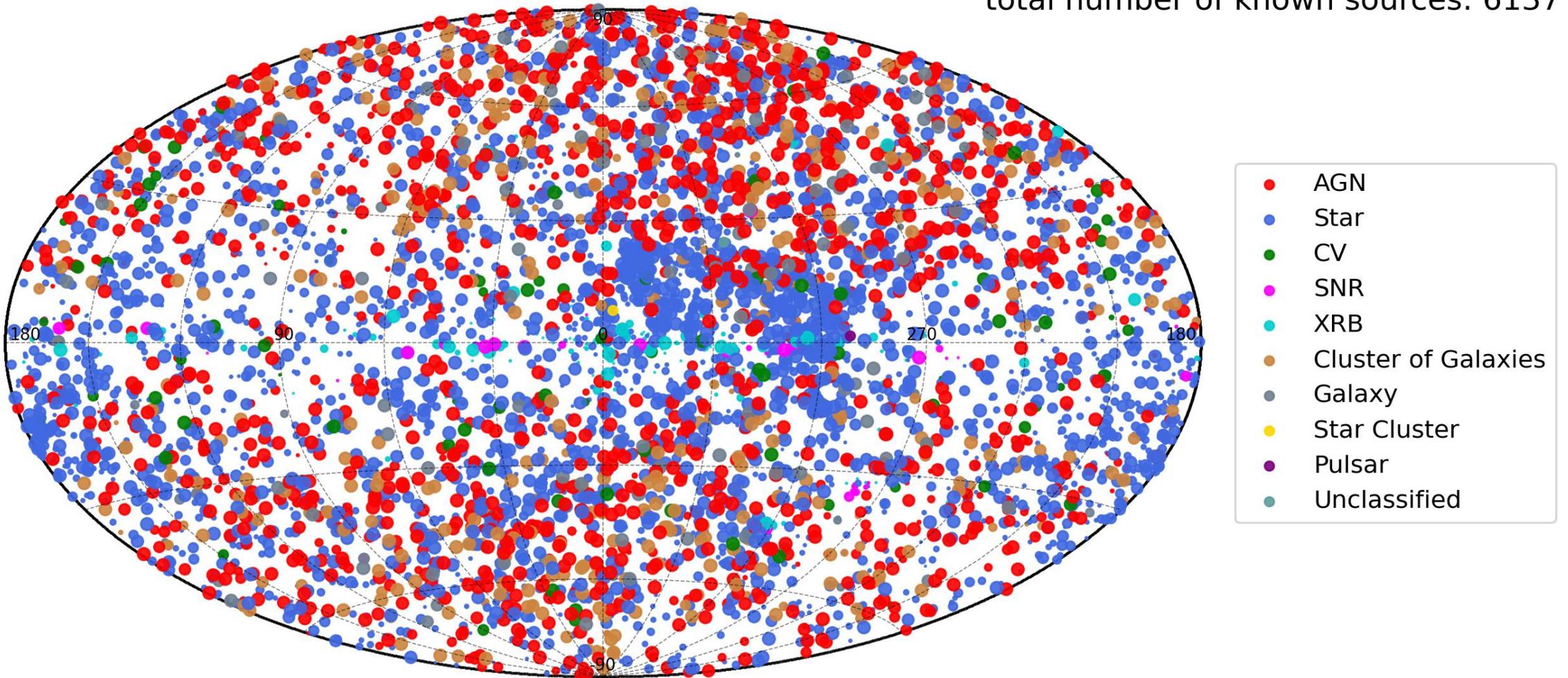
FXT X-ray spectrum obtained at the same time



EP-WXT sources

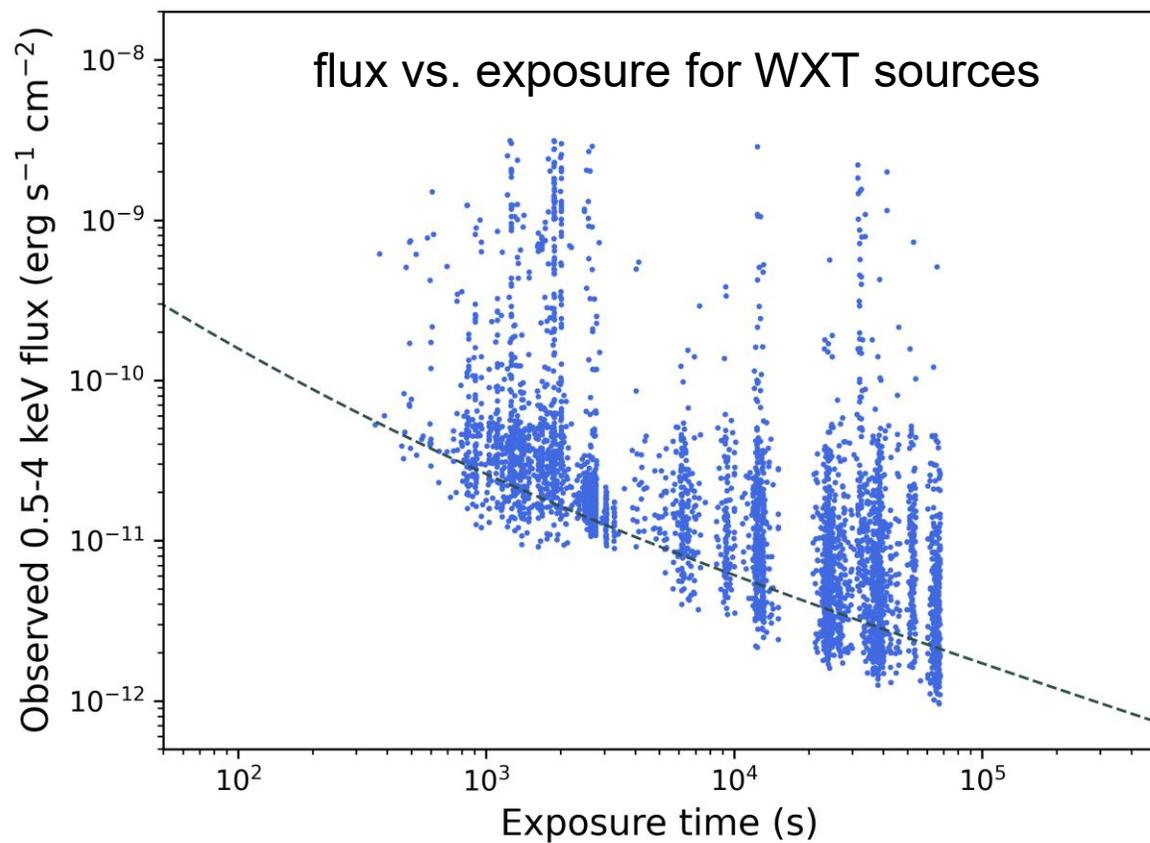
Galactic coordinate

total number of known sources: 6137

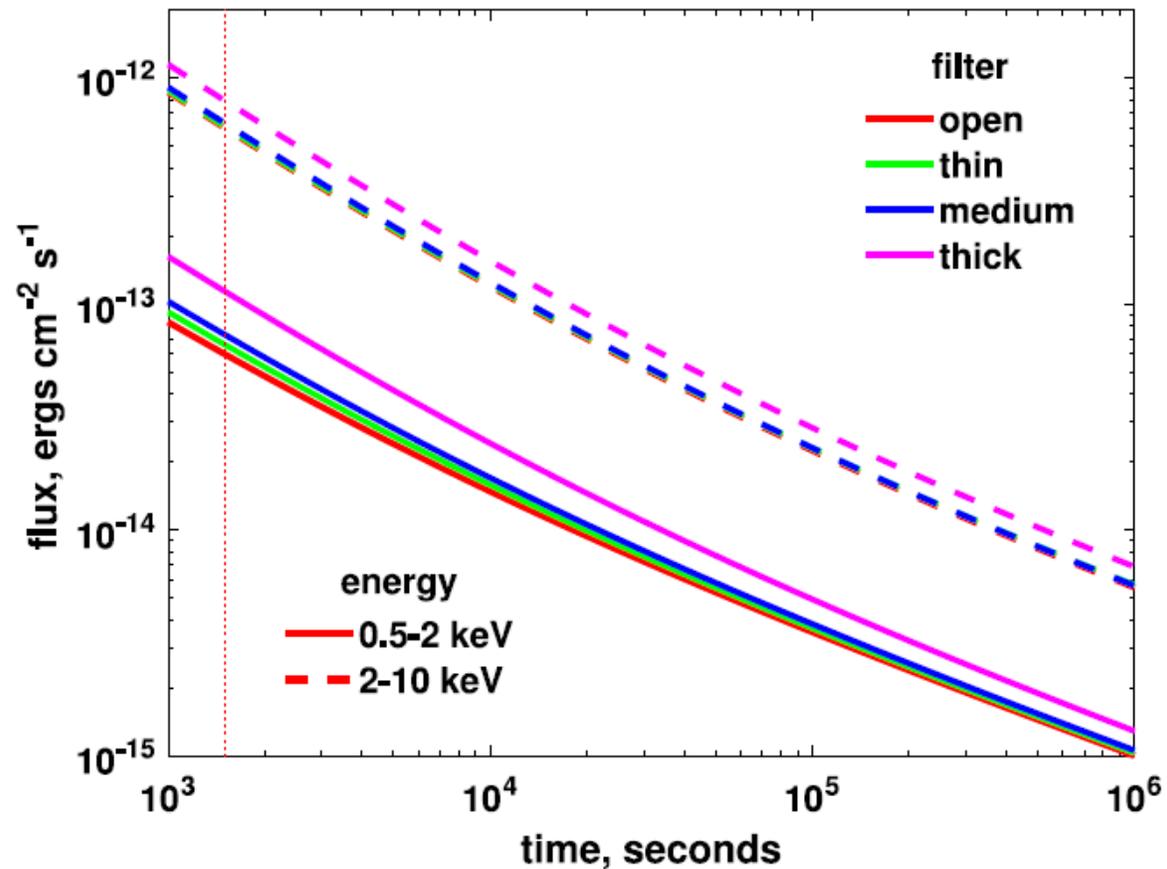


Sensitivity

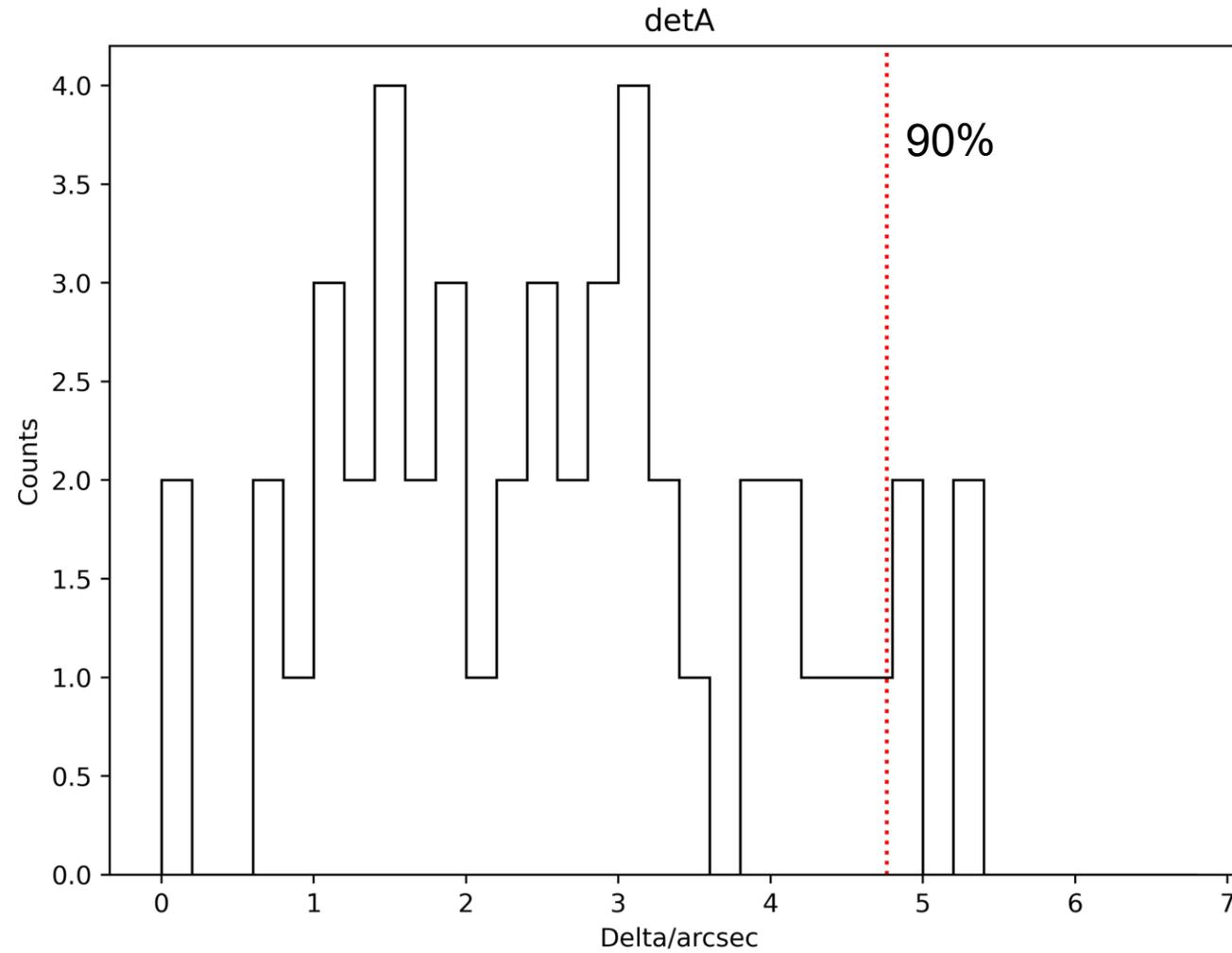
WXT



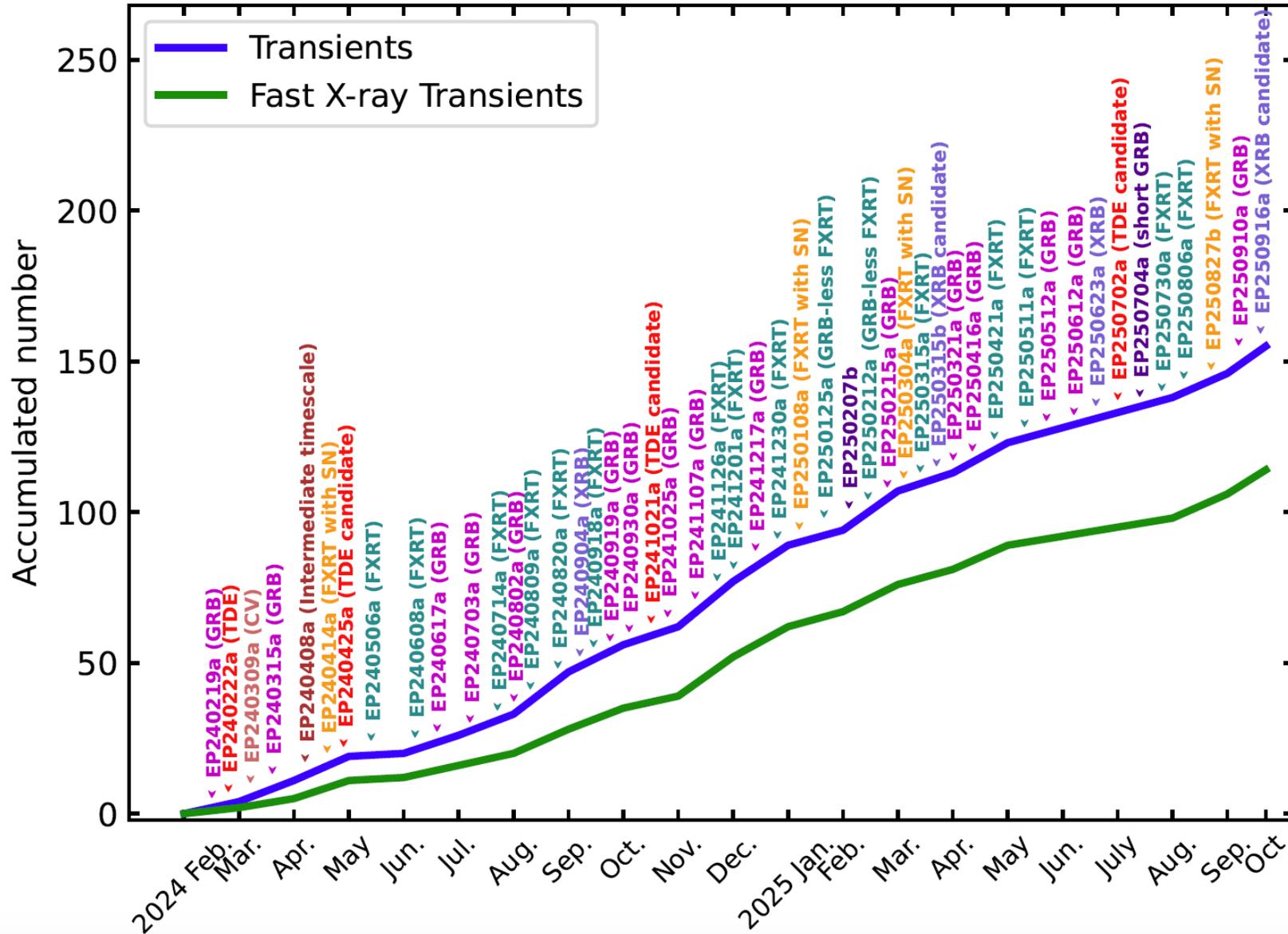
FXT (1 unit)



FXT localization precision for bright sources



X-ray transients detected with WXT (high S/N)



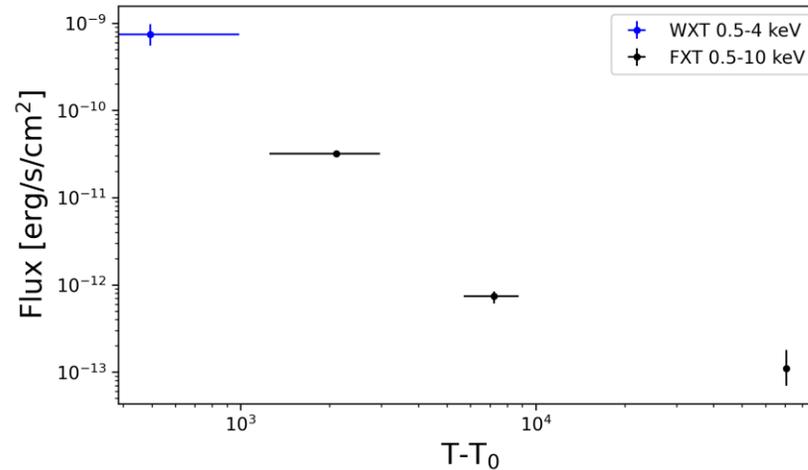
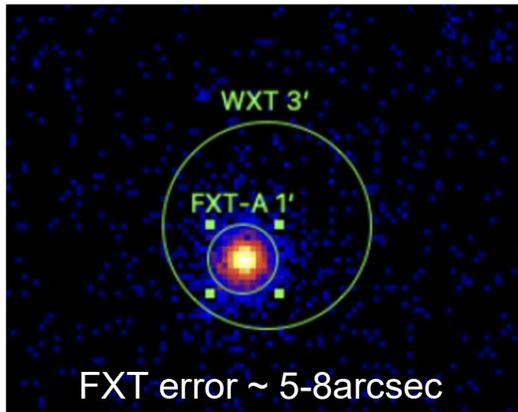
>200 GNCs & ATels issued

only 30-40 eFXT known before the launch of EP

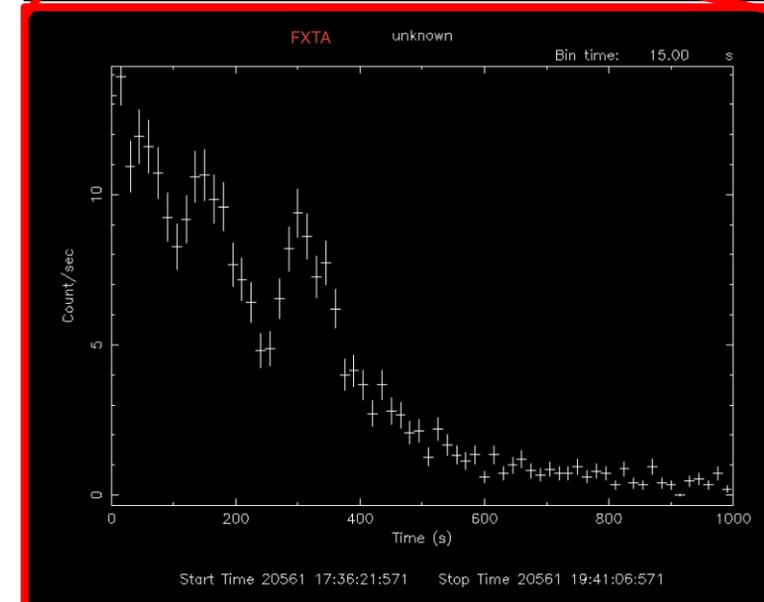
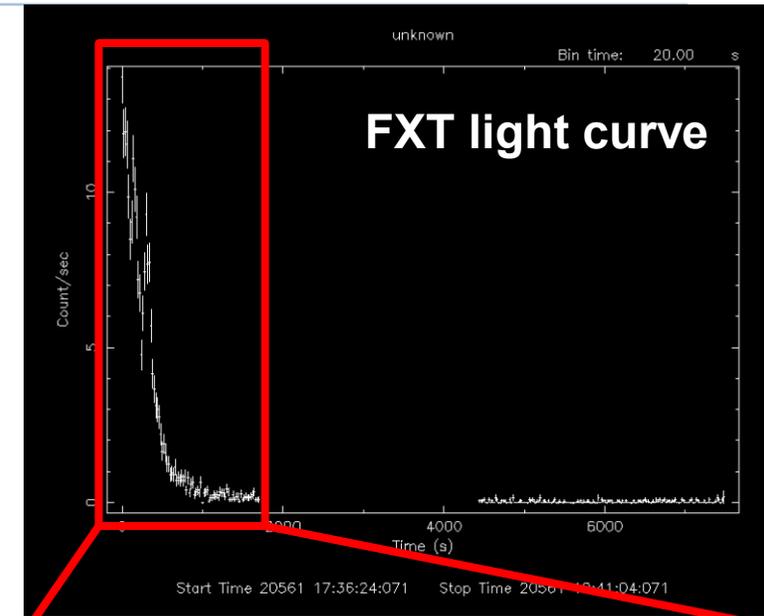
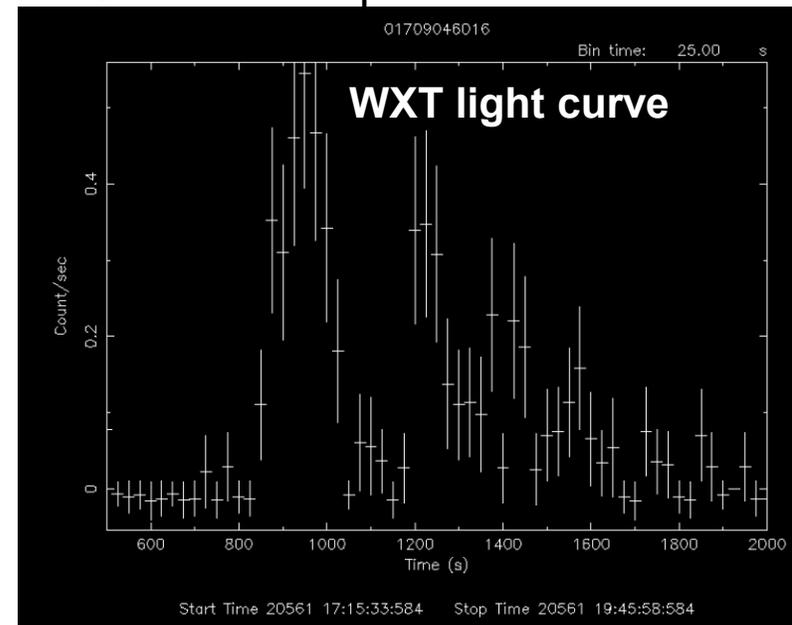
- X-ray transients ~100 /yr
- Fast X-ray transients ~80 /yr

Example of EP detection & follow-up: EP240908a:

- WXT onboard trigger:
T0=2024-09-08T17:28:27 (UTC)
peak flux: $\sim 1e-9$ erg/s/cm²
(EP team et al. GCN 37443)
- T0+7min: automated FXT follow-up
(EP team et al. GCN 37432)
- T0+19hrs: FXT ToO
 - flux $\sim 1.1 \times 10^{-13}$ erg/s/cm²
- optical afterglow candidate:
AB magnitude r ~ 24
(Quirola-Vasquez et al. GCN 37438)



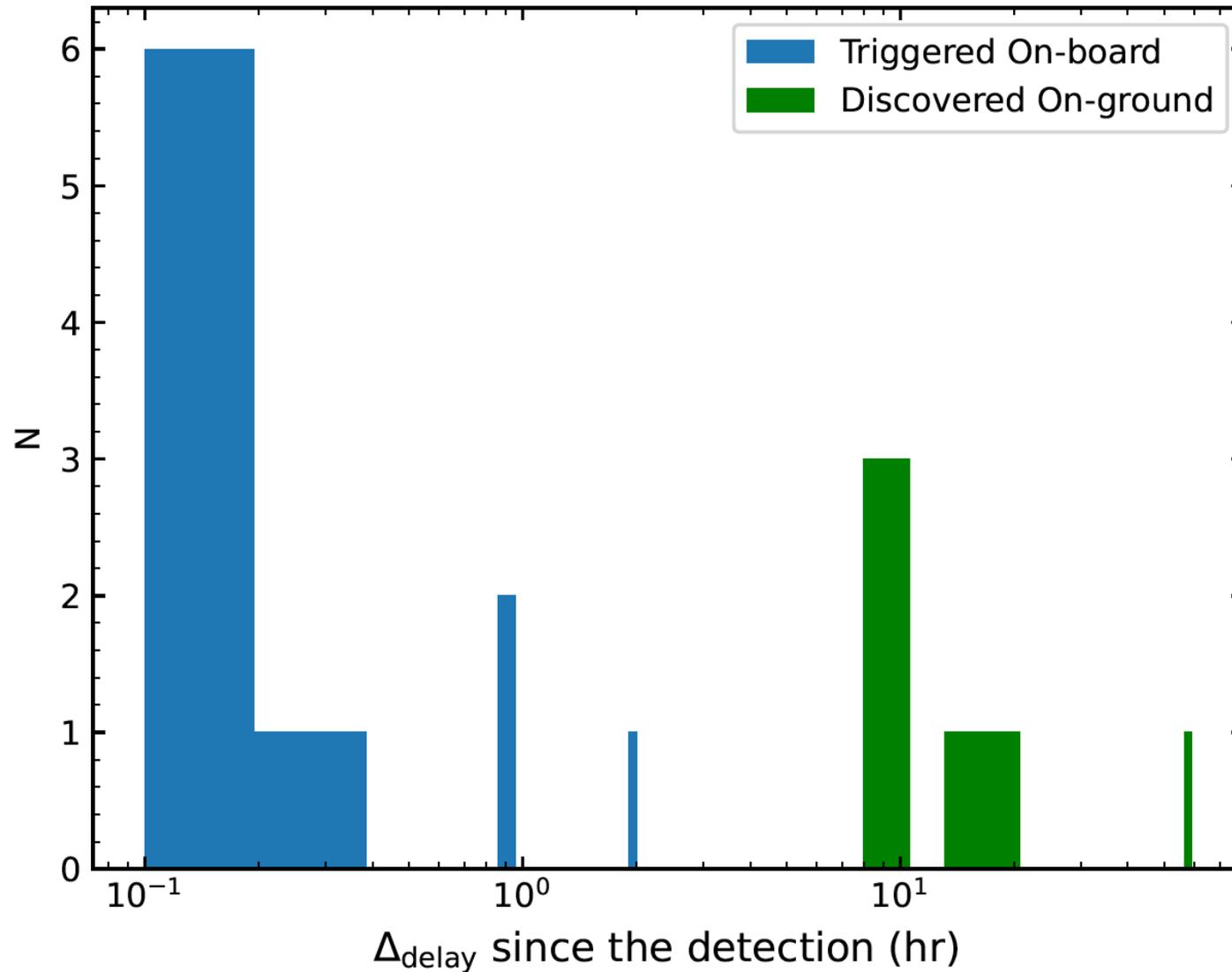
no GRB counterpart



Alerts of transients & science data

- ☰ Transient alerts: source position, flux, time, hardness ratios
- ☰ Onboard transient search and trigger
 - Alert information quick downlink: minutes, via BD system (China)/VHF (CNES/France)
 - Announced immediately to the community via GCN notice
- ☰ On-ground transient search and trigger
 - Analysis of telemetry data by transient advocates (TA)
 - Refined parameters of onboard triggers and fainter transients not triggered onboard
 - Alerts announced via GCN circulars or ATels (latency: several to ~ 10 hours)
- ☰ Science data
 - X-band telemetry: it takes from several hours to half a day to reach EP Science Centre
 - Will be made public after proprietary period of one year
 - EP data public: first batch release by end of 2025 (FXT end October)

Typical latencies for issuing transient alerts



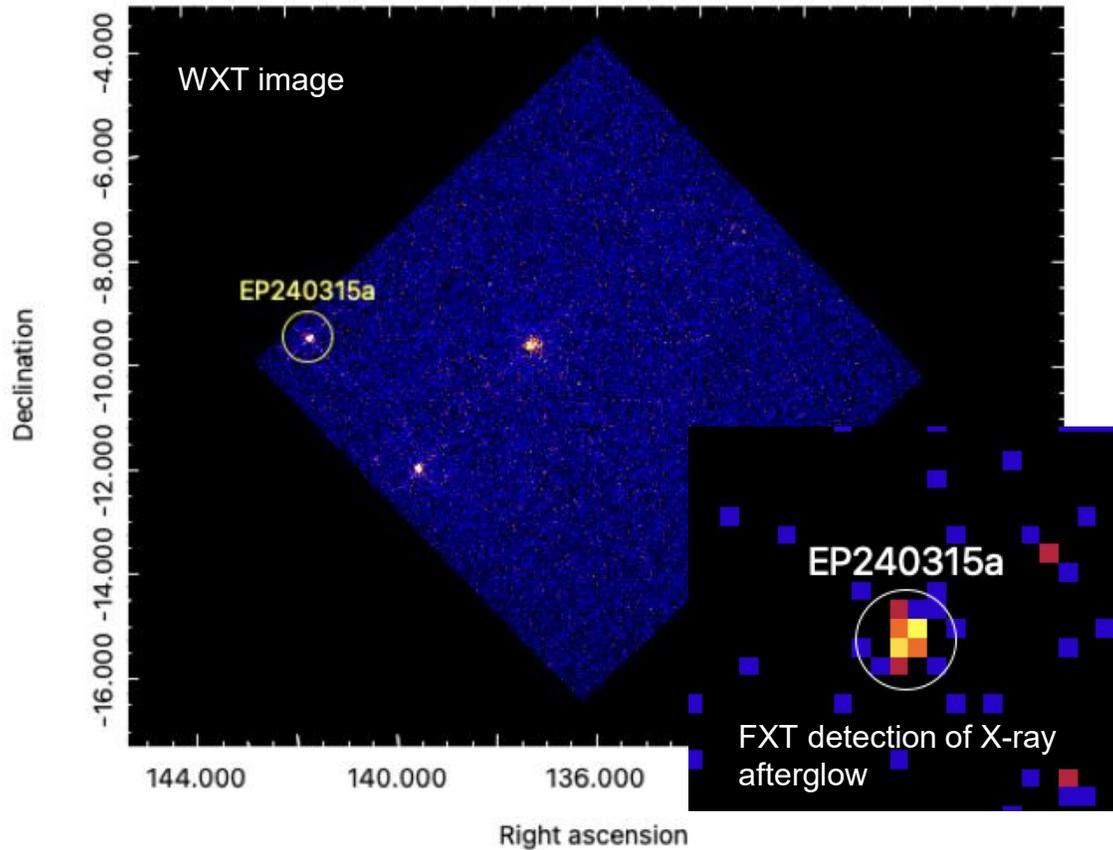
to be improved



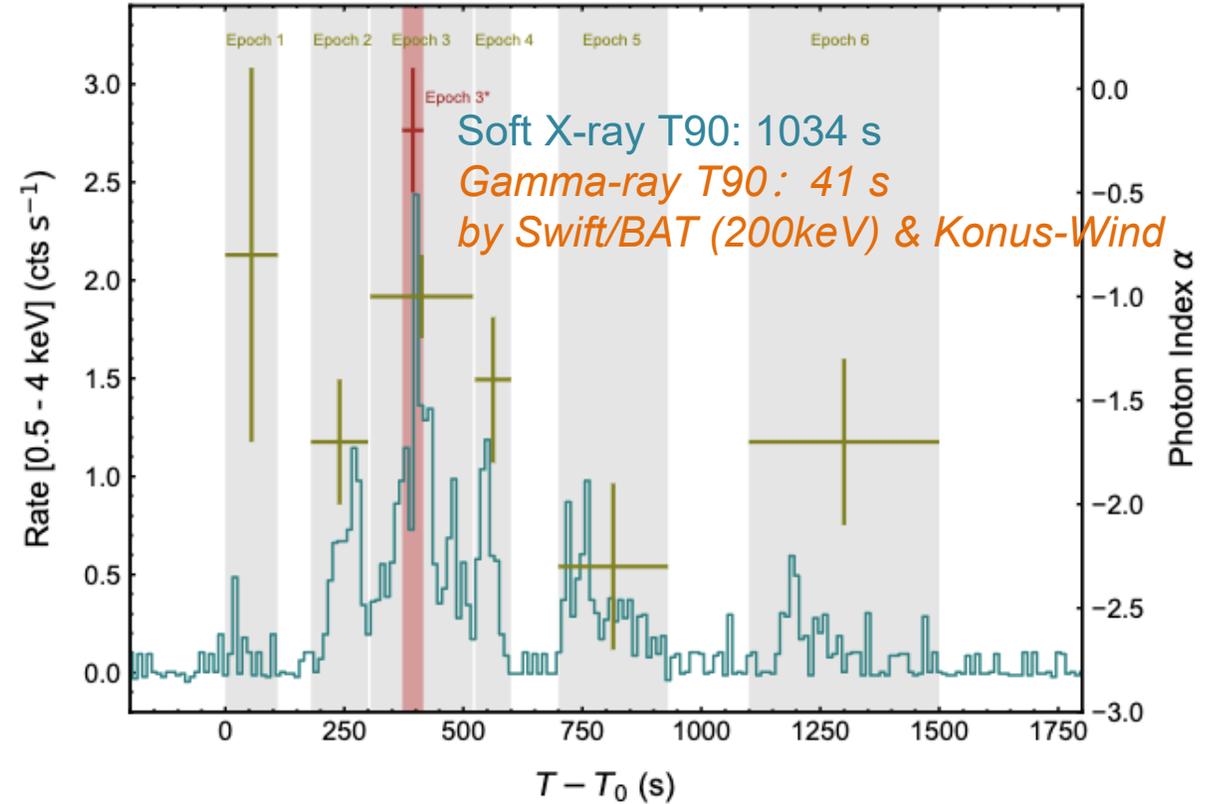
- Fast X-ray transients (FXTs) ~120
 - FXTs without GRBs: ~40
 - GRBs: ~40; soft X-rays precede GRBs and lasting longer significantly
 - FXTs with supernovae: EP240414a, EP250108a, EP250304a, possibly 2 more
- Tidal disruption events (candidates)
 - EP240222a, EP240425a, EP241021a, EP250702a
 - 3 jetted, 2 with possible IMBH, 1 white dwarf
- Transients from X-ray binaries in the Galaxy and nearby galaxies
 - Outbursts from known objects: many
 - New objects: several; EPJ182730.0–095633 (BHC), EP240809a (NS)
- Likely previously unknown types: e.g.
 - EP240408a (Zhang et al. 2024), EP240414a (Sun et al. 2025)

EP240315a: GRB @redshift 4.859

a



Onboard trigger, confirmed by on-ground analysis



Marked difference in LC of soft X-ray and hard X/ γ rays

Liu Y., et al. 2024 NA (arXiv:2404.16425)

Gillanders J.H., et al. arXiv:2404.10660 (ATLAS optical/radio counterpart, z)

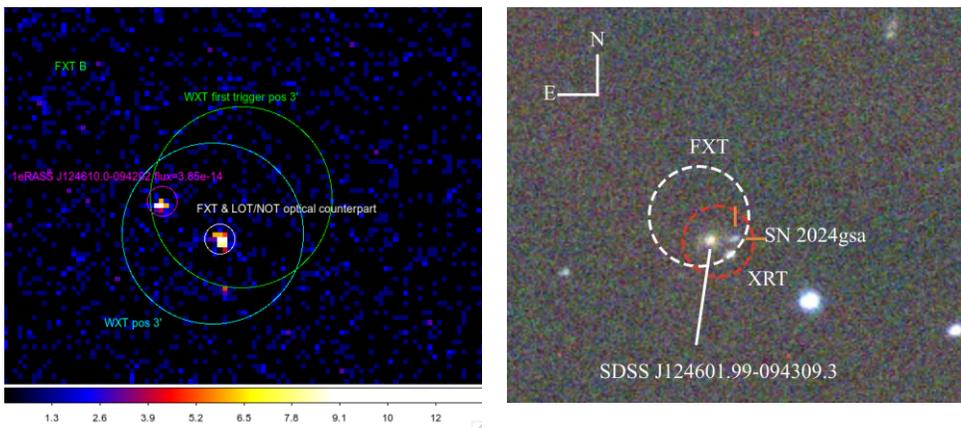
Levan A., et al. NA arXiv.2404.16350 (optical pho. and spec., z)

redshift 4.859 measured by VLT (Levan et al. 2024)

detectable by WXT at z~7.5

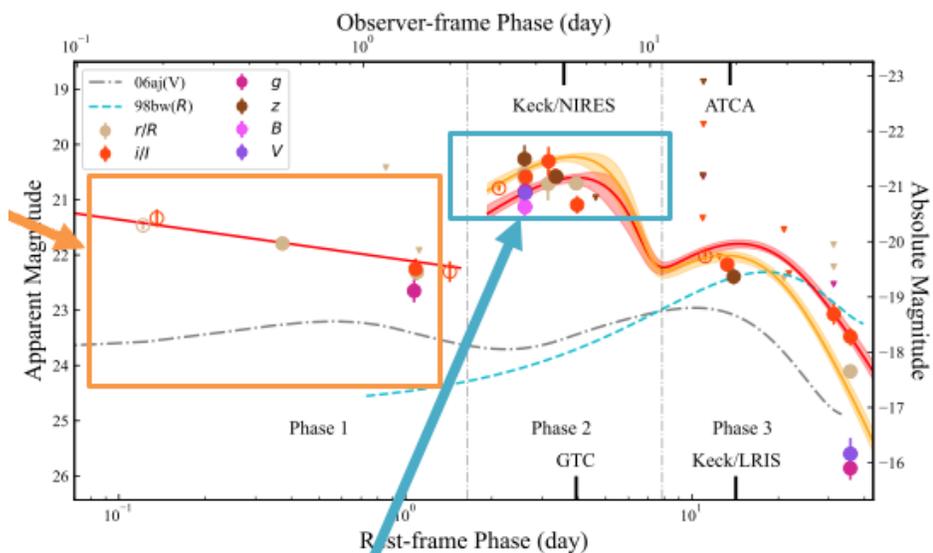
EP's potential of detecting high-z GRB !

EP240414a: new fast X-ray transient with SN ?

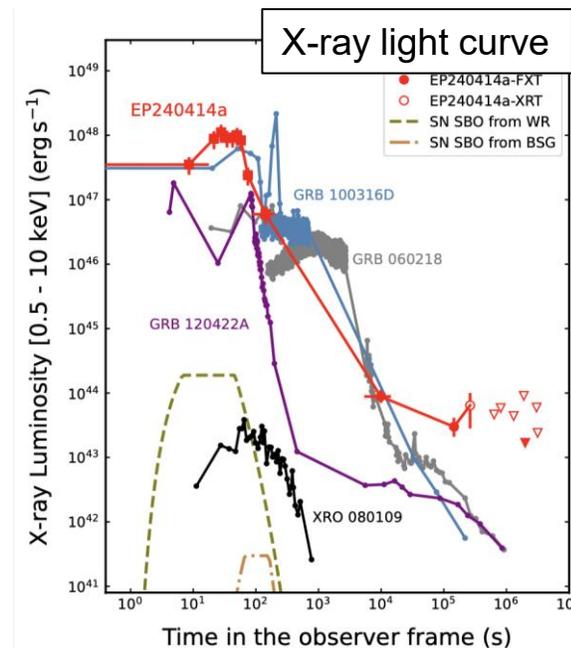
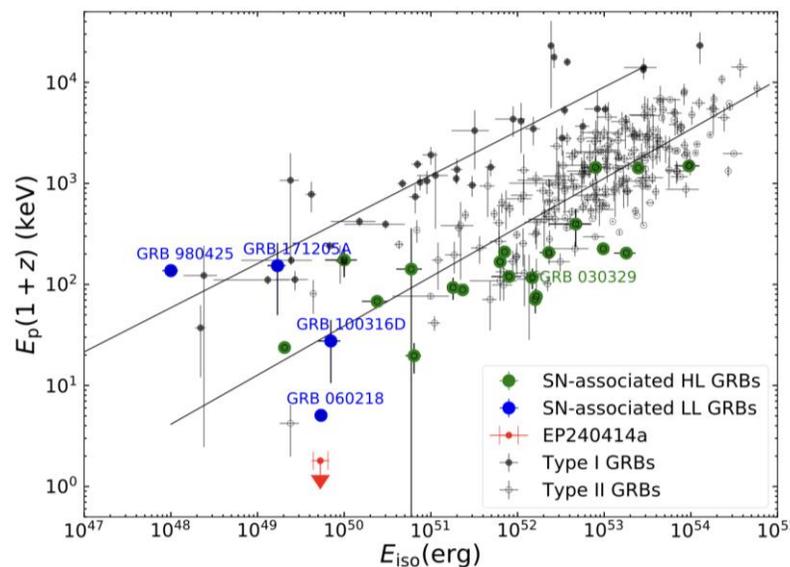


- Associated with type Ic-BL supernova 2024gsa $z=0.4$
- No associated GRB, very soft energy spectrum
- possibly a new type of FXT

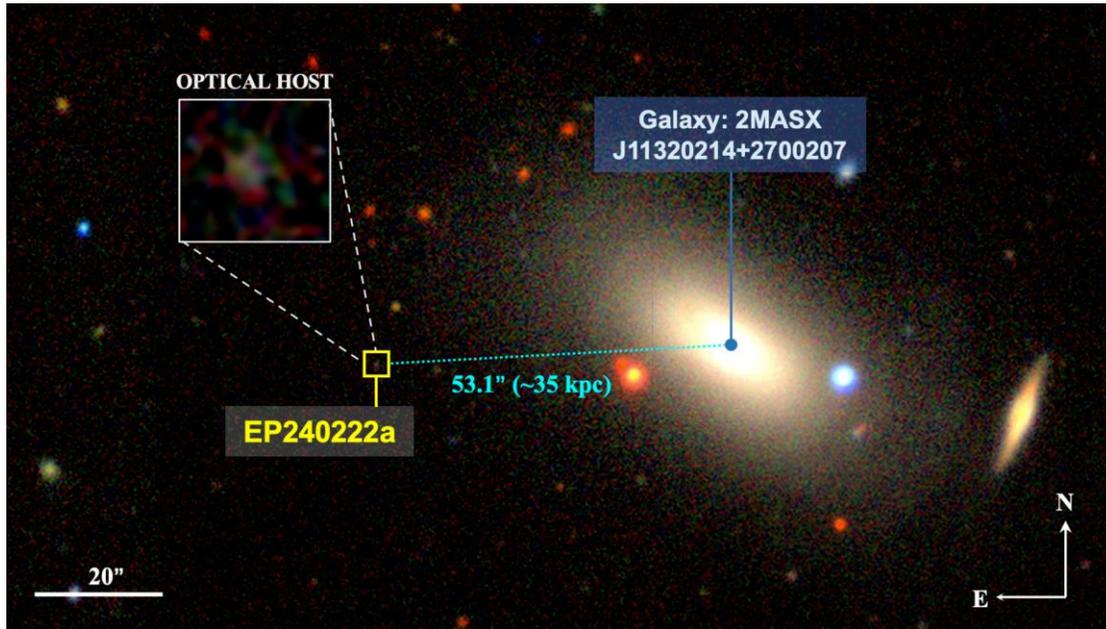
=> A weak relativistic jet that interacts with an extended shell surrounding the progenitor star



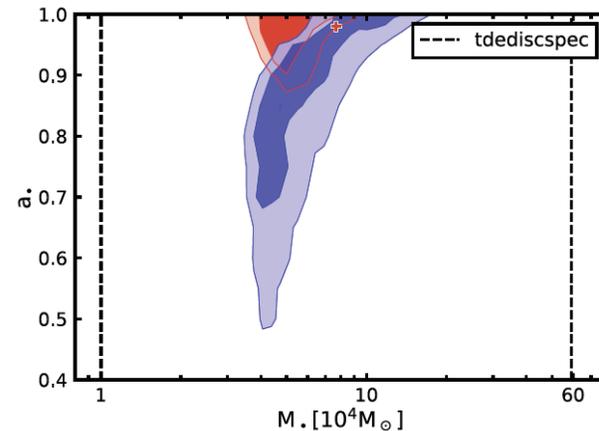
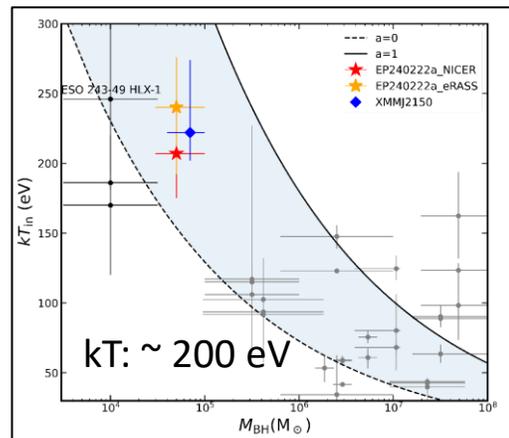
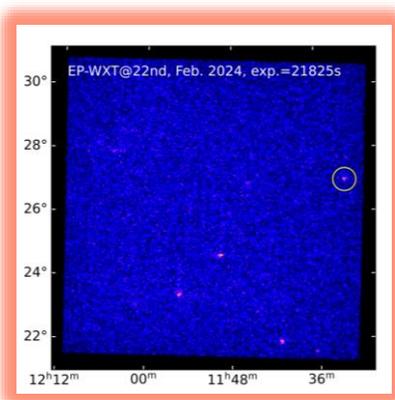
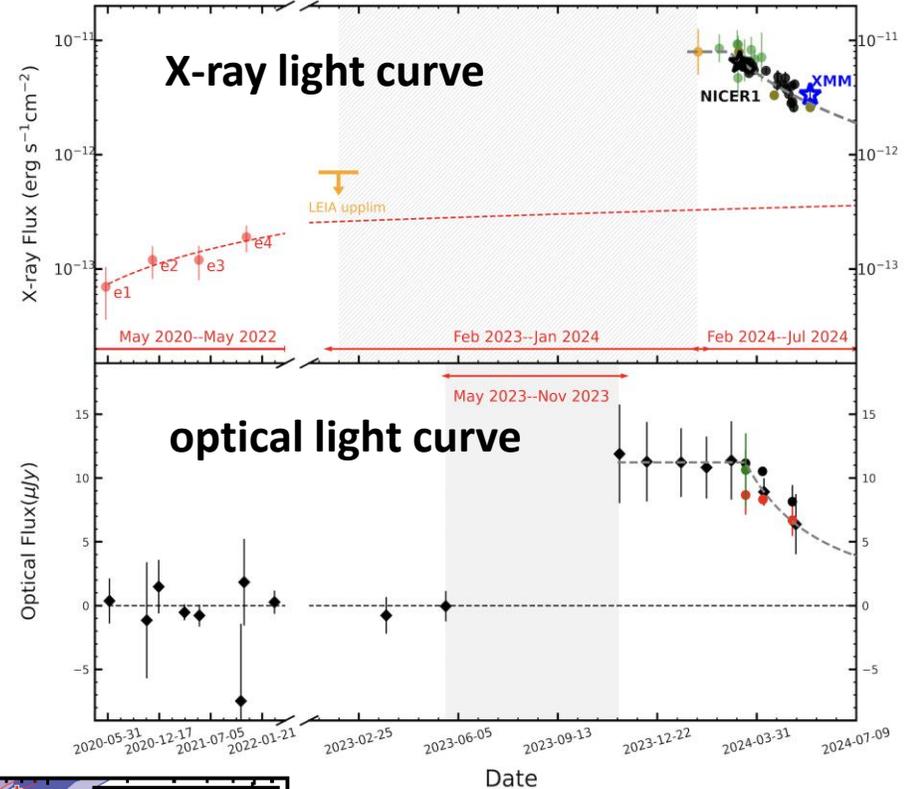
Shock breakout and cooling emission from the expanding hot material at large radii
an extended shell



EP240222a: TDE by IMBH in the halo of a large galaxy



>4 years; off nucleus: 35 kpc from center of a massive galaxy

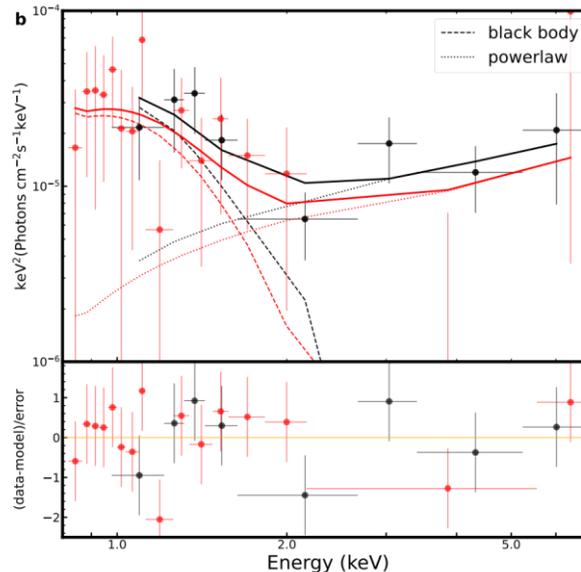
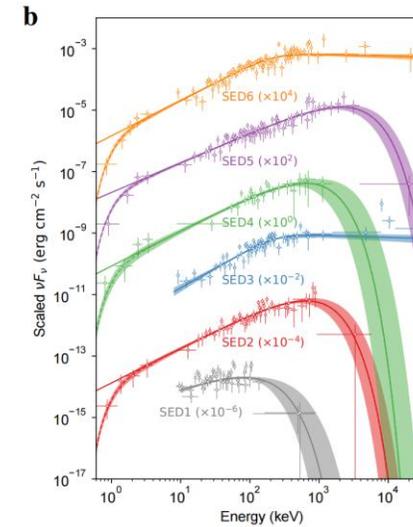
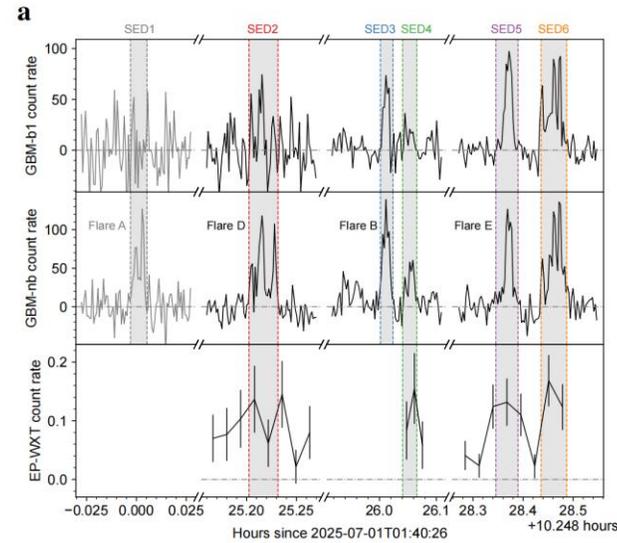
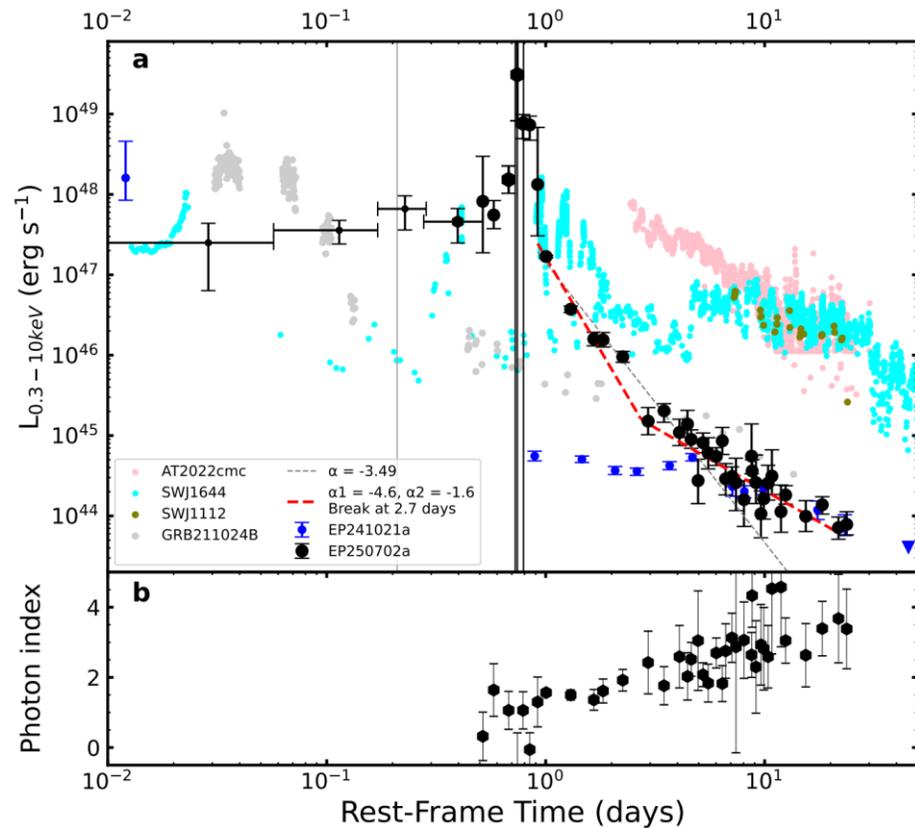


BH mass $1e4-1e5 M_{\text{sun}}$
 host stellar mass: $\sim 1e7 M_{\text{sun}}$

[Jin et al. 2025 arXiv:2501.09580](https://arxiv.org/abs/2501.09580)

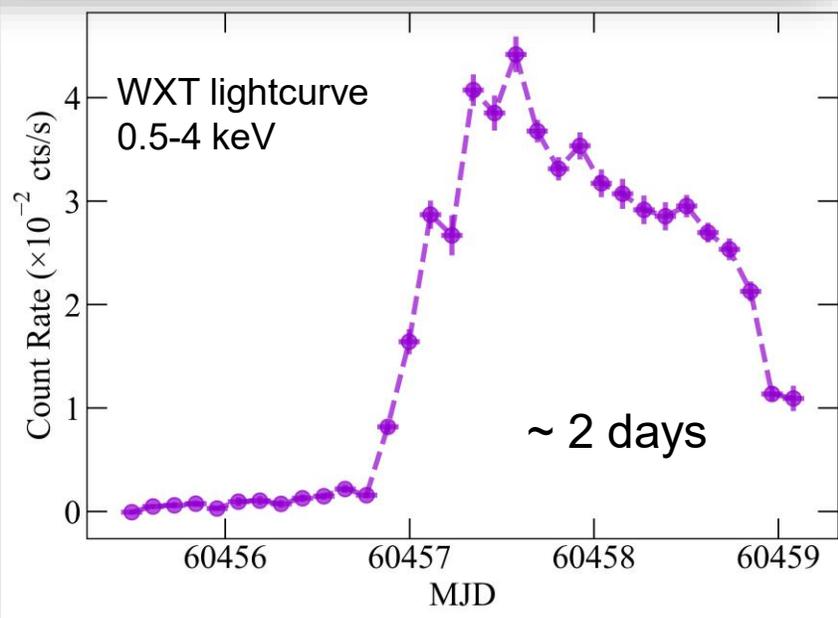
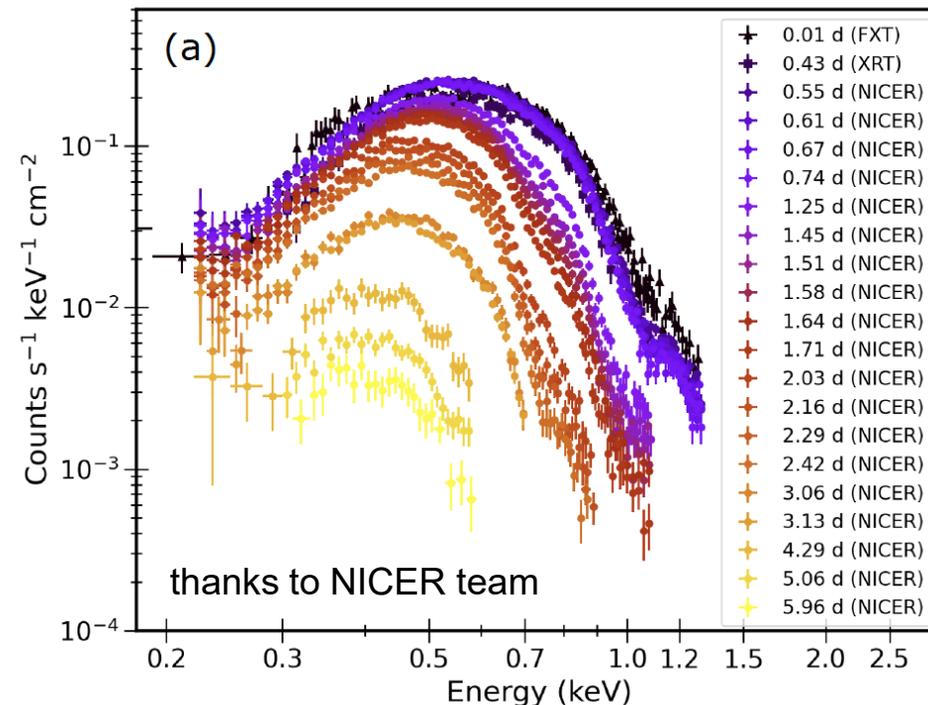
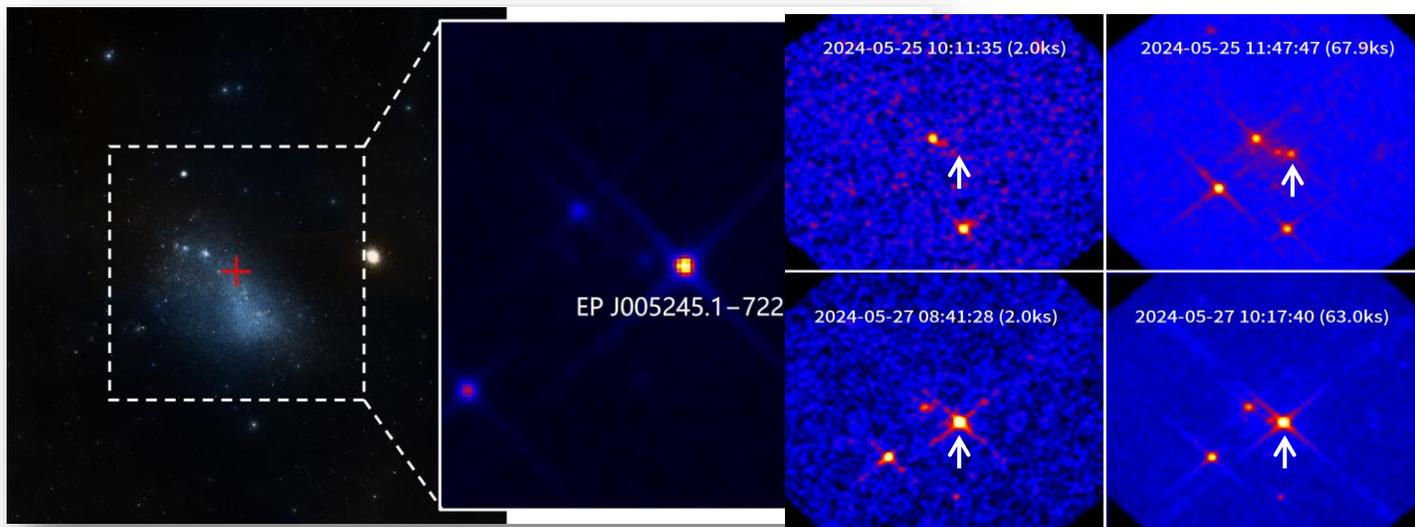
EP250702a: a likely IMBH jetted TDE disrupting a WD

Off-nuclear localization, at $z=1.036$



1. Recurrent X-ray, gamma-ray flares spanning $\sim 2(14)$ hours, spectra extending to MeV
2. Soft X-ray detection before the gamma-ray trigger
3. X-ray flux dropped by > 5 orders of magnitude within 20 days
4. X-ray spectrum softened, a possible thermal component emerged in later phase

An outburst in Small Magellanic Cloud: Be + WD



- CXOU J005245.0-722844 a weak Chandra source
- An X-ray outburst detected by [EP/WXT](#) (AteL#16631) and [Swift/XRT](#) (ATeL# 16633), follow-up by NICER (ATeL# 16636)
- very soft X-ray spectrum
- a possible Be binary system with a WD

X-ray follow-up of GW event: S250206dm

S240422ed: T0=2025-02-06 21:25:30.439 UTC; NSBH (55%), BNS (37%); 373 +/- 104 Mpc; 90% area=547 deg^2

EP follow-up observations:

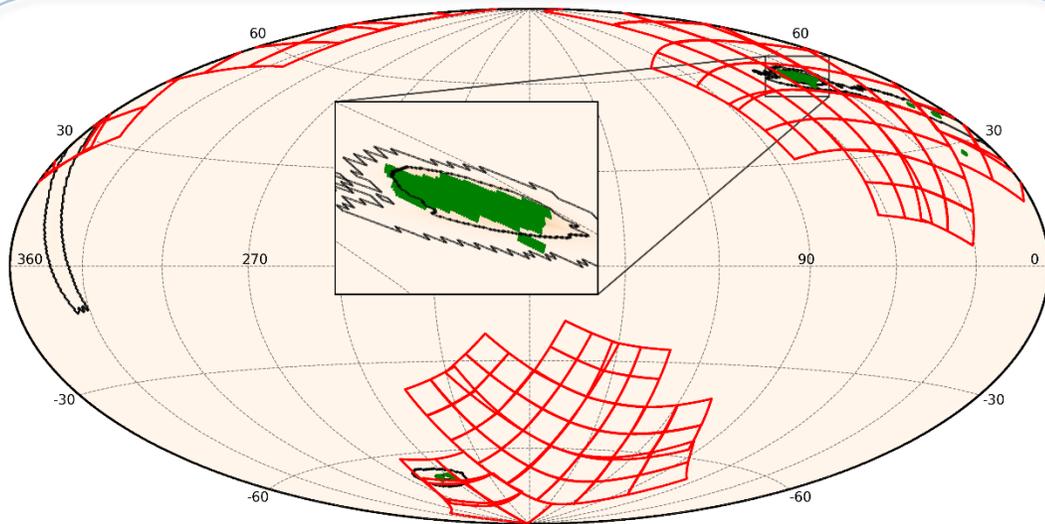
1st round: 2×2400s WXT coverage + 100×300s FXT targeting galaxies (2025-02-07T02:55:12Z ~ Feb. 8th)

2nd round: 59×2000s FXT tiling (from Feb. 11th to 18th)

Search for transient or variable candidates in the FXT data (apparently associated with the galaxies):

found ~20 uncatalogued sources, two of which exhibit significant flux decay.

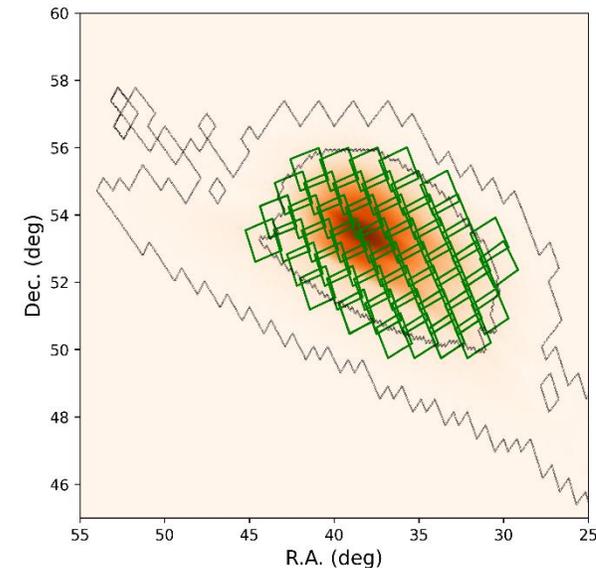
Detailed information: GCN Circular 39545; <https://ep.bao.ac.cn/ep/cms/article/view?id=185>



1st : WXT covered 302 deg^2 within (55% of) the 90% GW area

WXT 0.5-4 keV flux limits: $1 \times 10^{-11} \text{ erg s}^{-1} \text{ cm}^{-2}$

FXT 0.5-10 keV flux limits: $3 \times 10^{-13} \text{ erg s}^{-1} \text{ cm}^{-2}$



2nd : FXT covered 34 deg^2 within (89% of) the 50% GW area

FXT 0.5-10 keV flux limits: $5 \times 10^{-14} \text{ erg s}^{-1} \text{ cm}^{-2}$

Summary

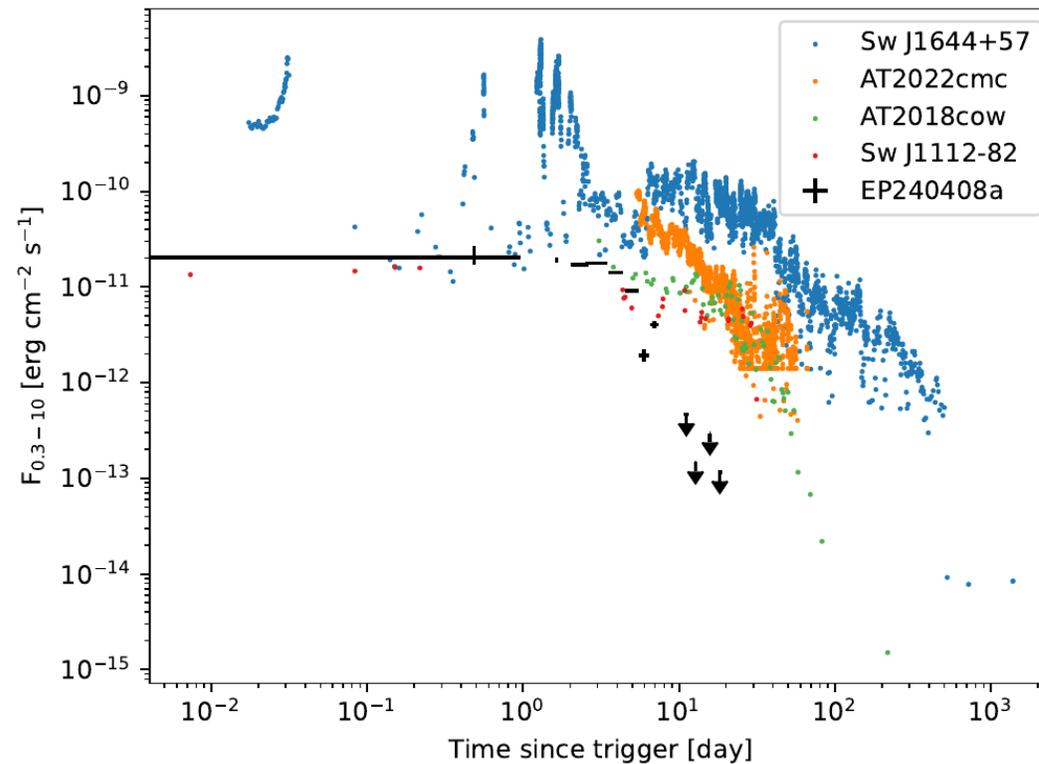
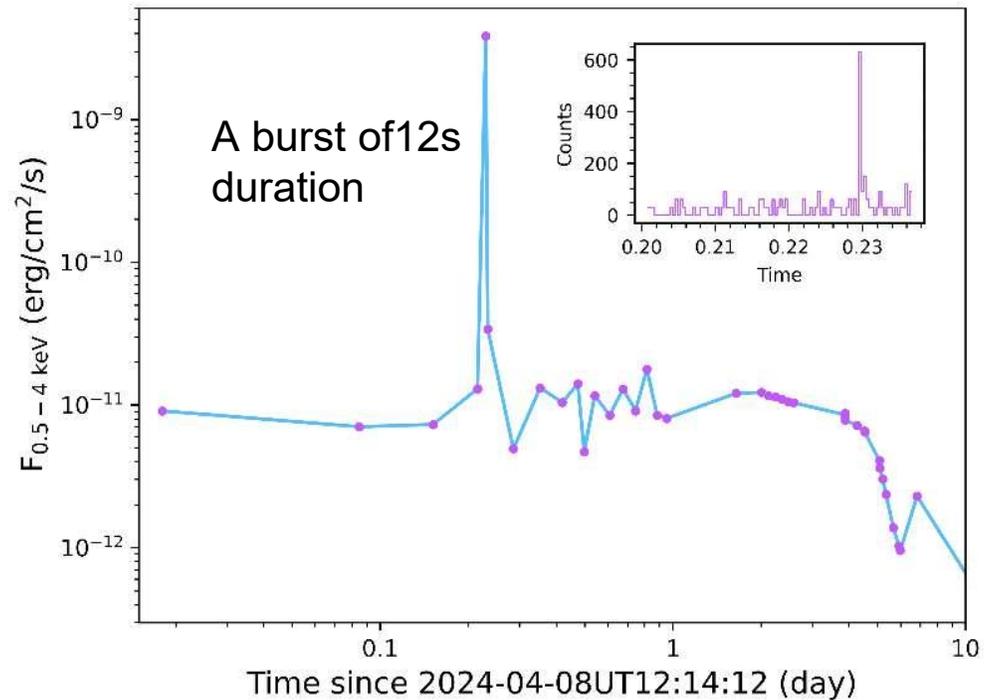
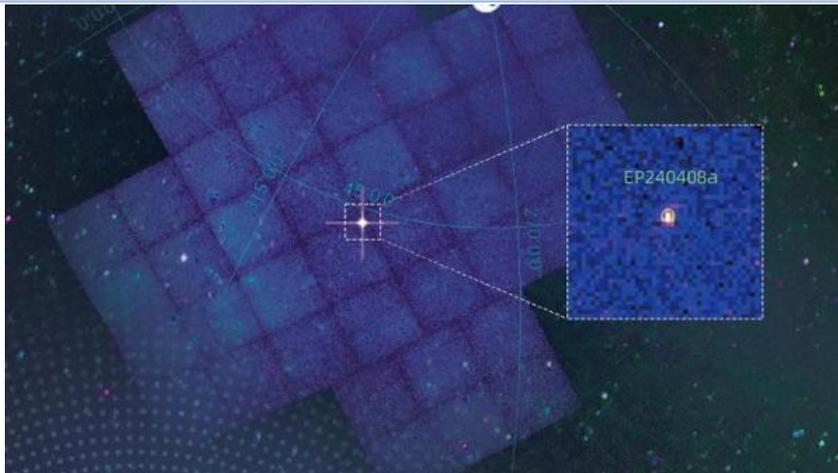


- Science operations have been started since July 2024
- ~150 X-ray transients with high/SN detected
- A wide range of targets: FXTs, GRBs, TDEs, WD+NS+BH, flaring stars, GW events
- Monitored the activity of large samples of known sources
- Alerts publicly announced via GCN/ATel
- More discoveries expected in X-ray time-domain and MM astronomy

<http://ep.bao.ac.cn>

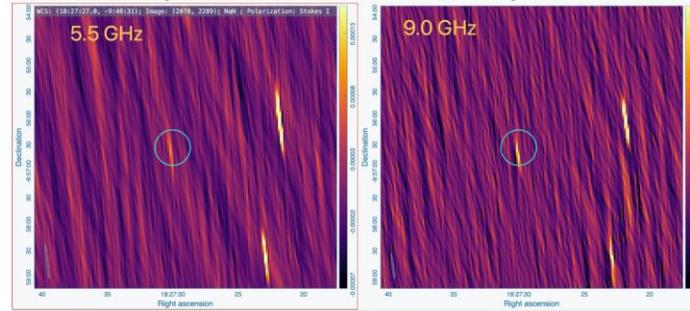
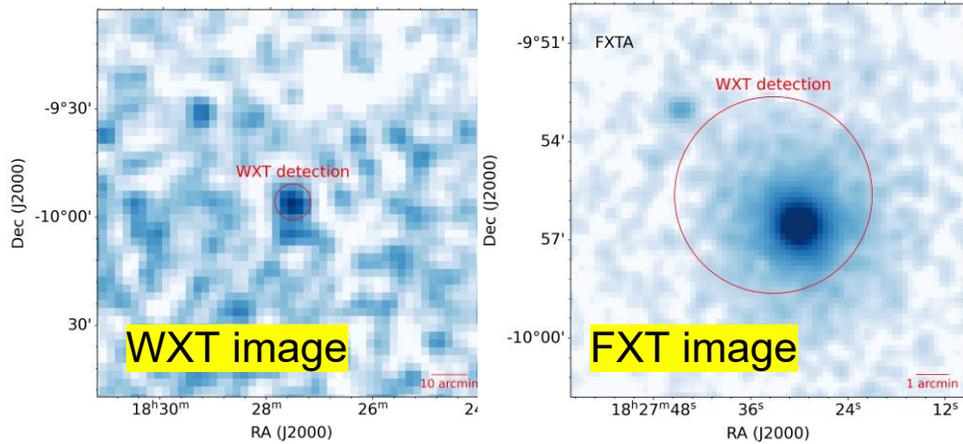
https://www.esa.int/Science_Exploration/Space_Science/Einstein_Probe_factsheet

EP240408a: peculiar intermediate-timescale transient



Spectral and temporal properties different from known transients;
possibly a new transient type
or IMBH-jetted TDE?

EP240904a: a new X-ray binary (BH?)



radio: flat spectrum @ X-ray
bright state: a compact jet

X-ray spectrum: power-law $\Gamma \sim 2$

EP J182730.0-095633: Atel # 16805, 16807, 16817, 16825; no optical/NIR counterpart found

