The Einstein Probe Mission

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On behalf of the EP team
National Astro. Observatories, CAS

Image credit CAS/ESA

2024-6-18 CXU meeting

Einstein Probe (EP) mission

basic goals

- Discover X-ray transients & monitor source variability with improved sensitivity
- Characterise transients/variables by quick X-ray follow-ups
- Disseminate transient alerts to community in time

milestones

- Proposed (2012), R&D (2011-2017)
- Adoption (2017/12; planned launch 2022/12)
- Joined by ESA & MPE (2018), CNES (2022)
- Pathfinder ***LEIA*** launched (2022/07)
- Satellite FM assembly & tests (2023/06-11)
- **Launch**: Jan. 9 2024
- Lifetime: 3 yr (goal 5 yr)

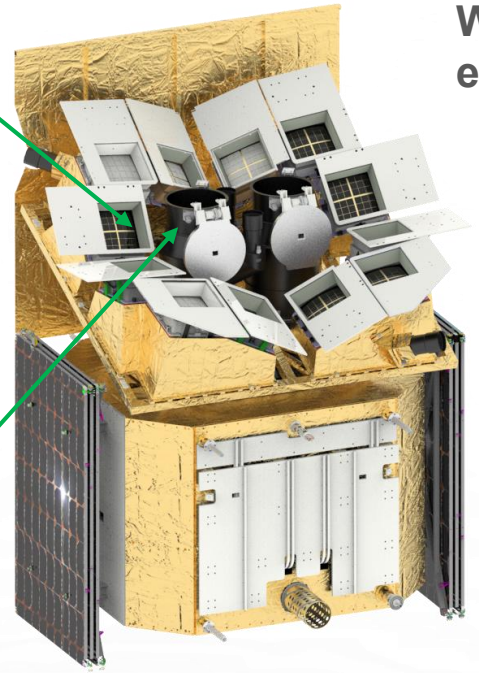
Instruments & spacecraft

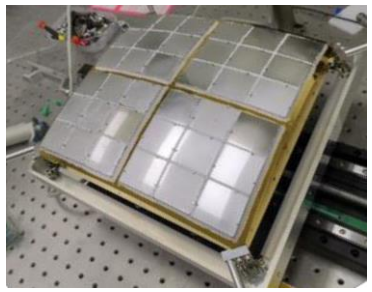
Wide-field X-ray Telescope
WXT (12 modules)

Lobster-eye MPO + CMOS
FoV: ~3,600 sq deg (1.1 sr)
Band: 0.5 – 4 keV
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
Resolution: 24” (HPD, on-axis)
Effe. area: ~300 cm² @1keV (x 2 units)





WXT mirror & CMOS detectors (1 module)

Spacecraft

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

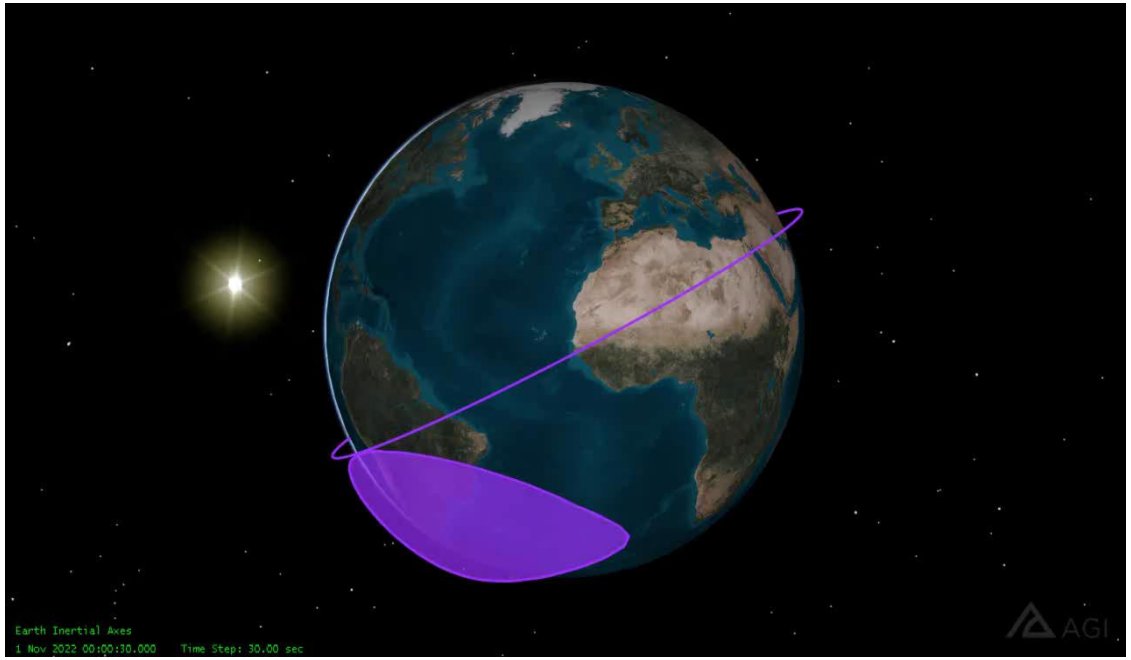
Telemetry

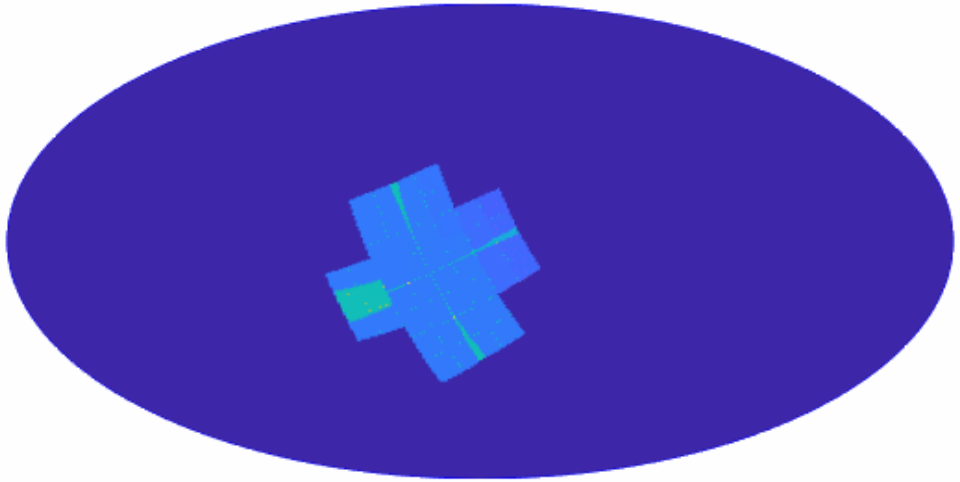
X/S-band (several hours)
BD (down/up-link; minutes)
VHF (down-link; minutes)

Yuan, et al. 2022 *Handbook of X-ray and Gamma-ray Astrophysics*

Observation modes

- Circular orbit
  - Height 592km, period 96min
  - inclination angle 29 deg.
- **Observation modes**
  - **Survey (primary WXT)**
  - **Autonomous follow-up (FXT)**
  - **ToO (FXT, WXT)**
  - **Calibration**
- **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 ½ year**
  - **FXT pointed to pre-selected targets**



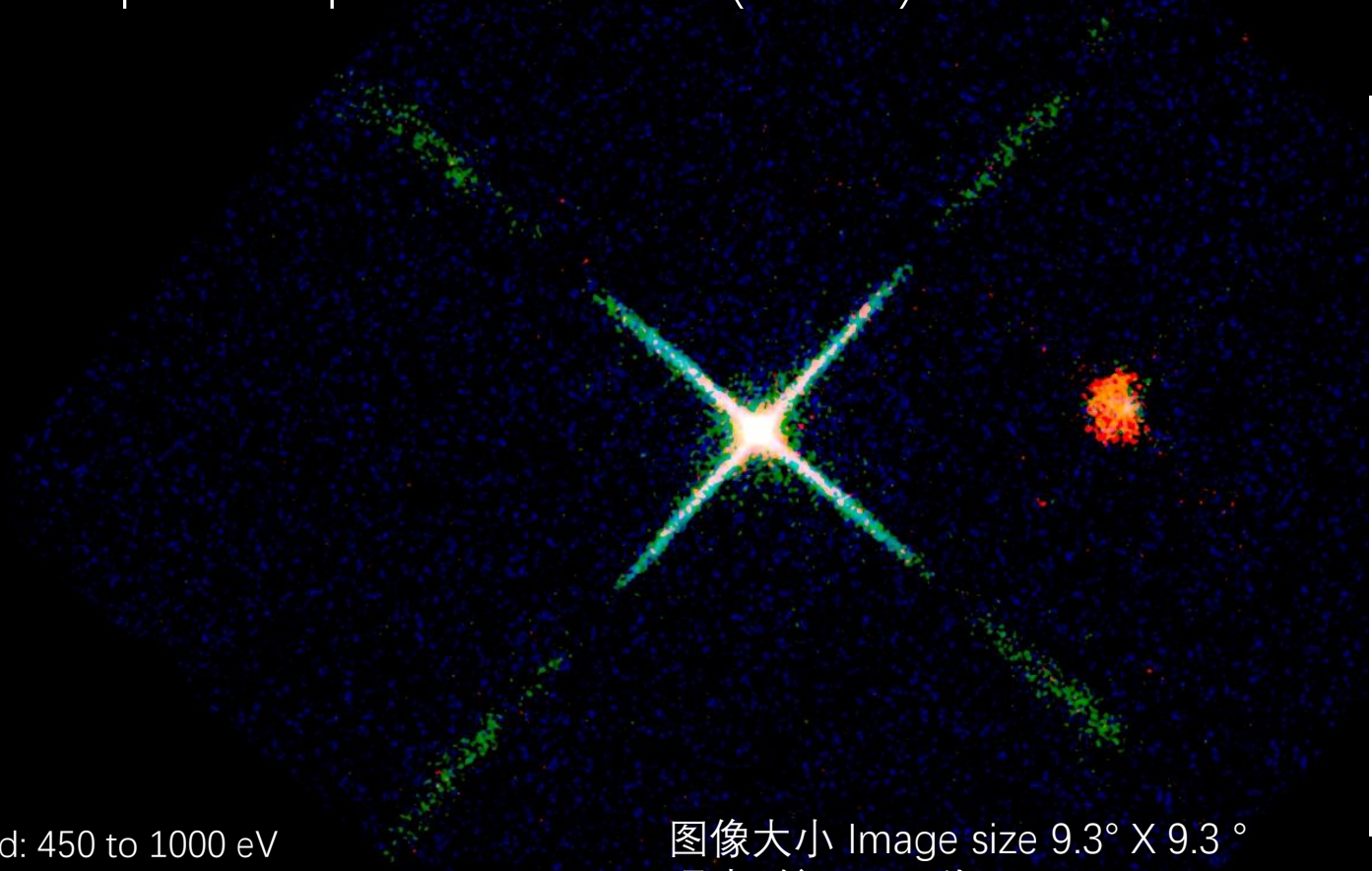


Status: commissioning phase

- Most in-orbit verifications have been completed
  - Spacecraft and payloads
  - Satellite-ground interface and workflow （X-band, VHF)
- First light achieved for WXT (Jan. 19) and FXT (Feb. 22)
- Performance verification observations for one week (Mar. 22)
- WXT calibration mostly completed; FXT calibration on-going
- Spacecraft & instruments working normally
- EP Science Centre (EPSC): commissioning tests
- TBD: automated FXT follow-up obs. triggered onboard
- Commissioning completion: June 2024
- Formal science operations: plan to start in June

WXT 首光X-射线图像 X-ray First light　2024 Feb. 19

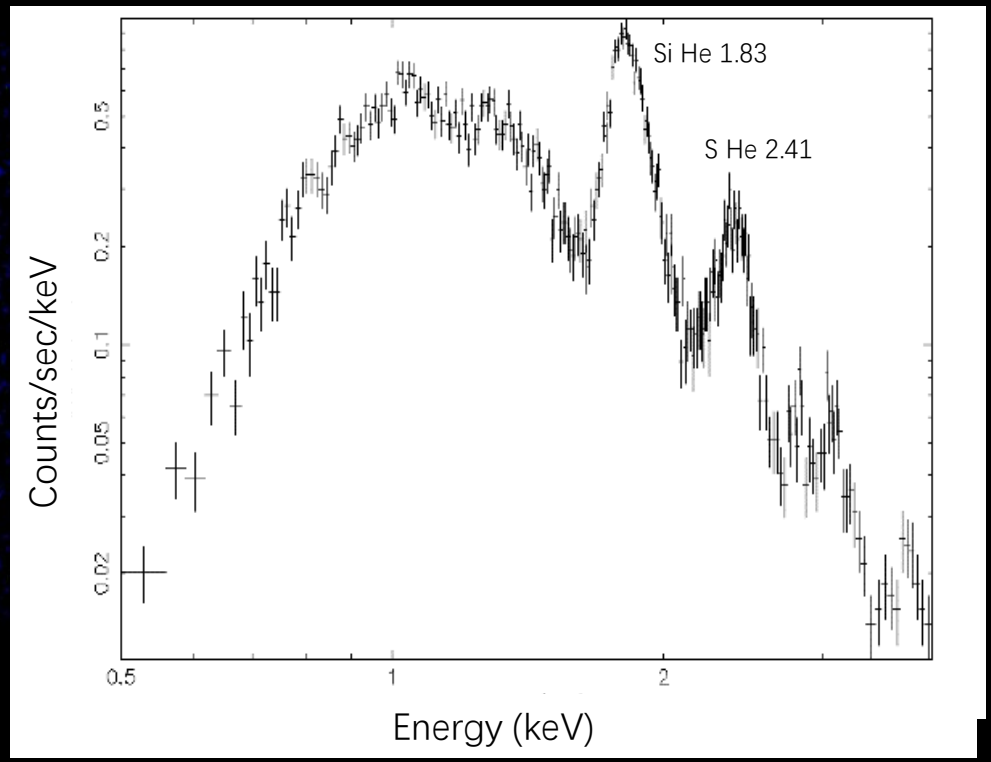
仙后座 A 超新星遗迹（星云）
Cassiopeia A supernova remnant (nebula)



Red: 450 to 1000 eV
Green: 1000 to 2000 eV
Blue: 2000 to 5000 eV

图像大小 Image size 9.3° X 9.3 °
曝光时间2.2万秒
exposure 22 kilo-seconds

同时获得的X 射线光谱
X-ray spectrum obtained at the same time



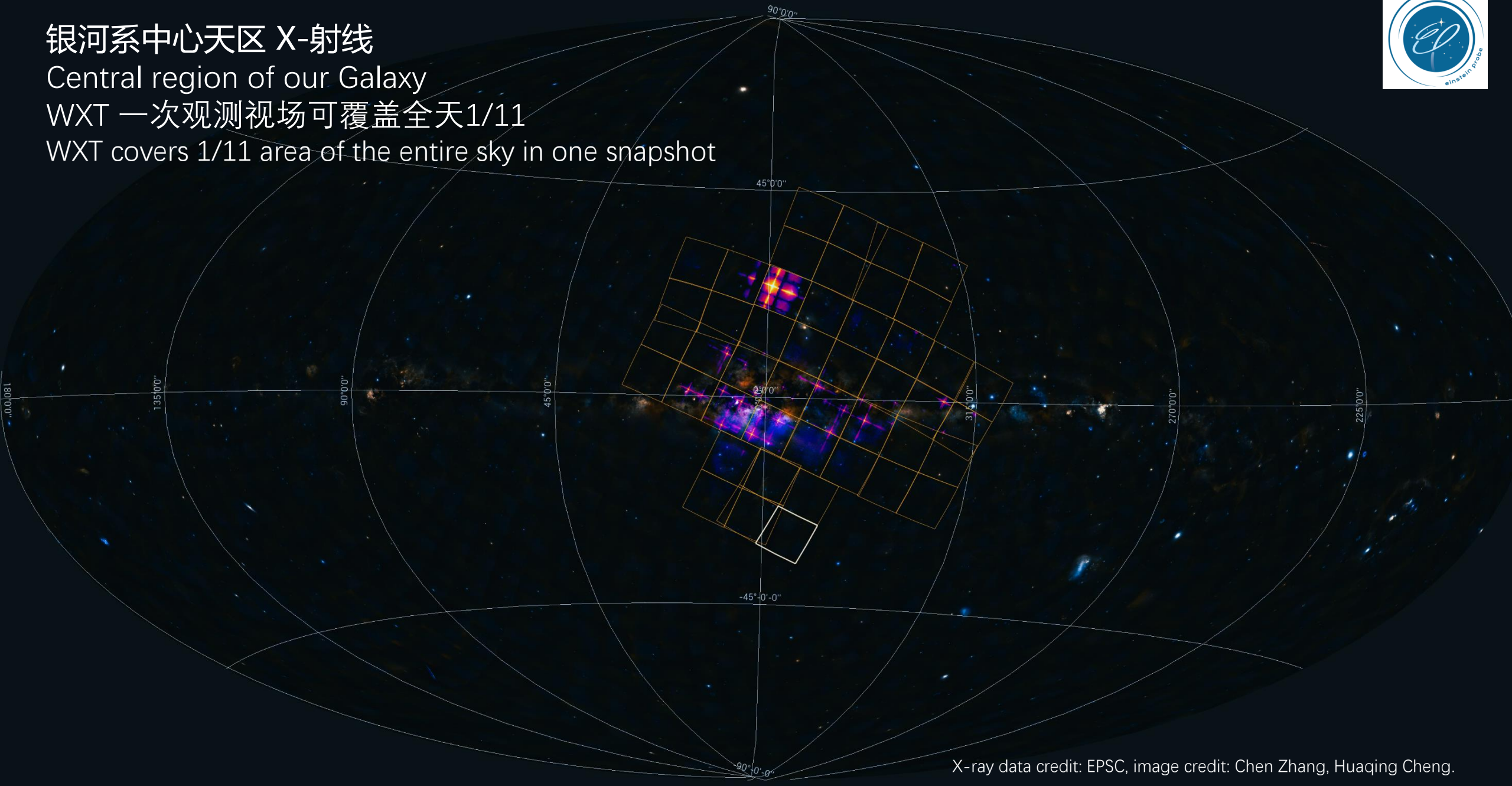
X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.

银河系中心天区 X-射线

Central region of our Galaxy

WXT 一次观测视场可覆盖全天1/11

WXT covers 1/11 area of the entire sky in one snapshot

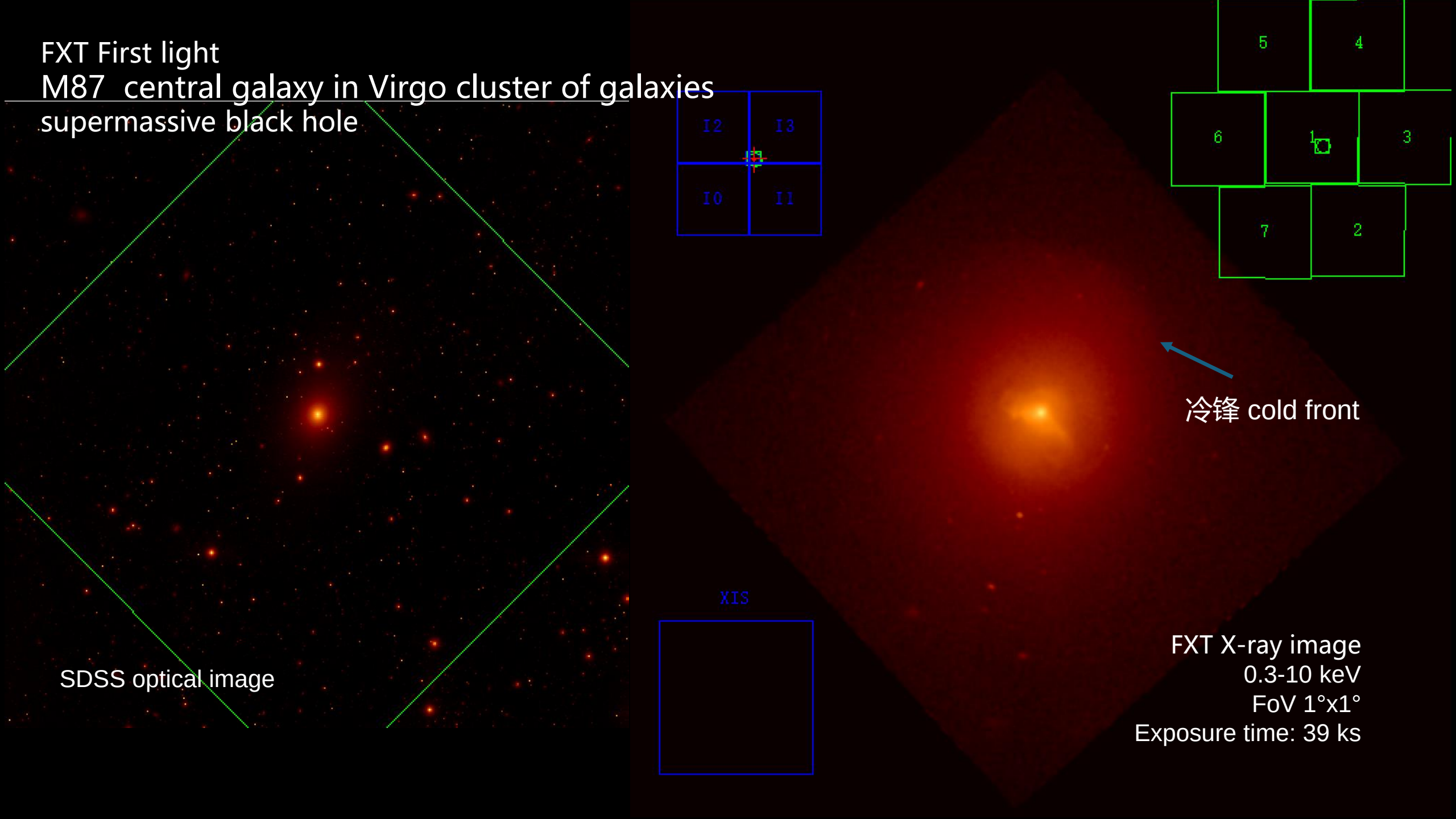


X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.

FXT First light

M87 central galaxy in Virgo cluster of galaxies

supermassive black hole



冷锋 cold front

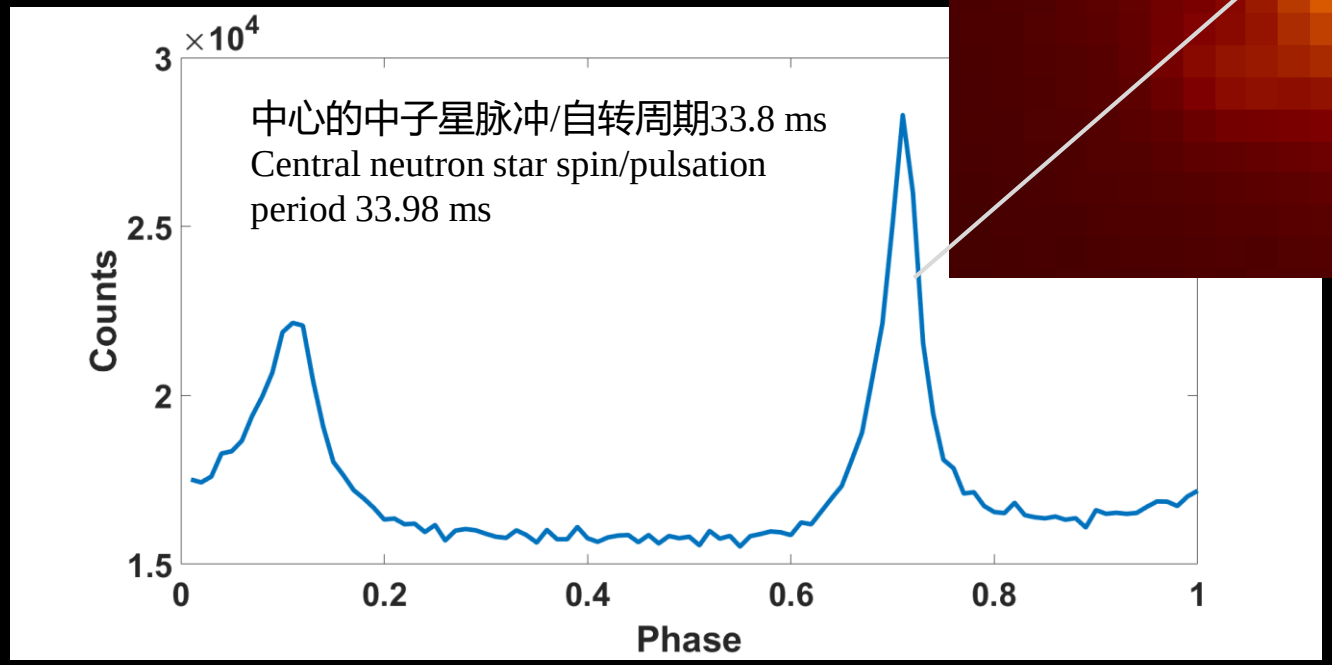
SDSS optical image

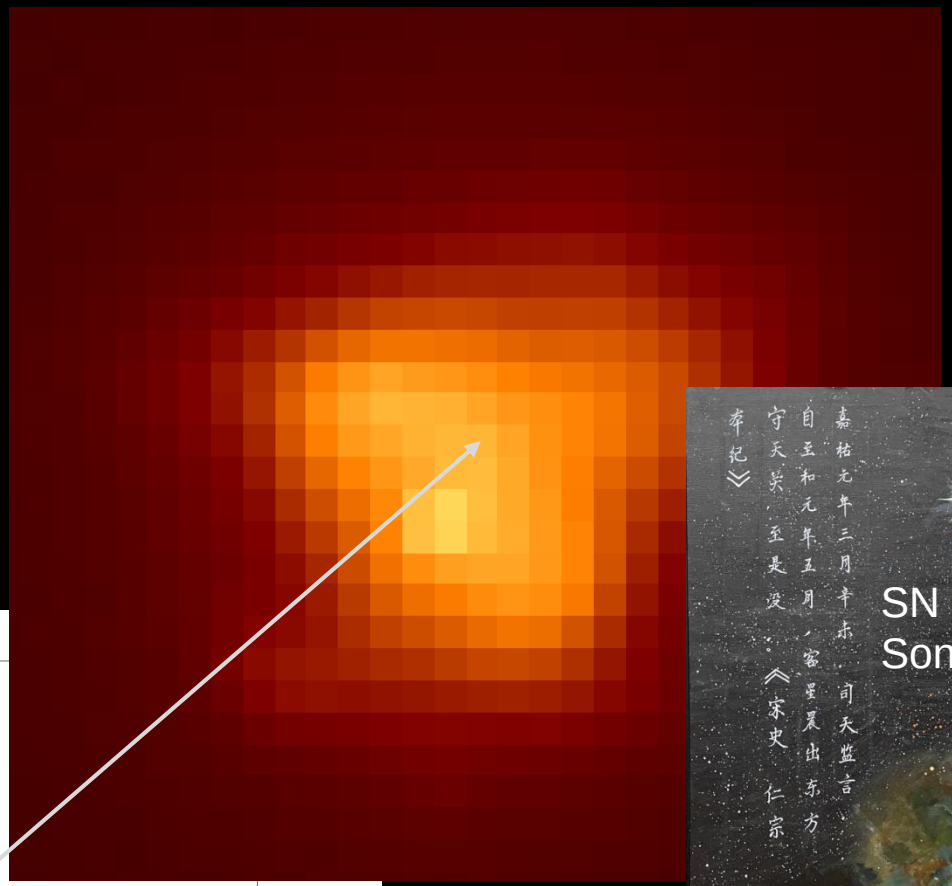
FXT X-ray image
0.3-10 keV
FoV 1°x1°
Exposure time: 39 ks

FXT 首光X-射线图像
FXT X-ray First light

蟹状星云 超新星遗迹
Crab nebula supernova remnant

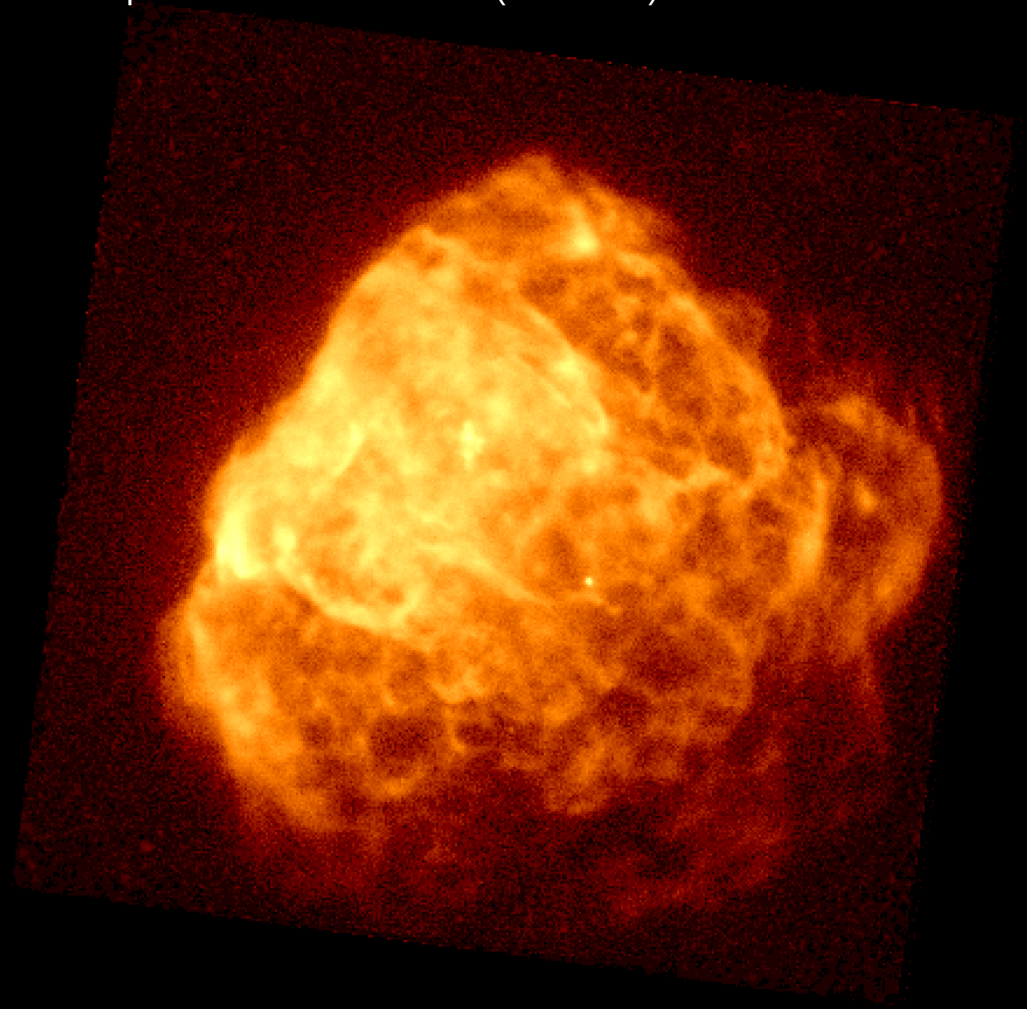
能段 0.3-10 keV
曝光时间 Exposure 2600s



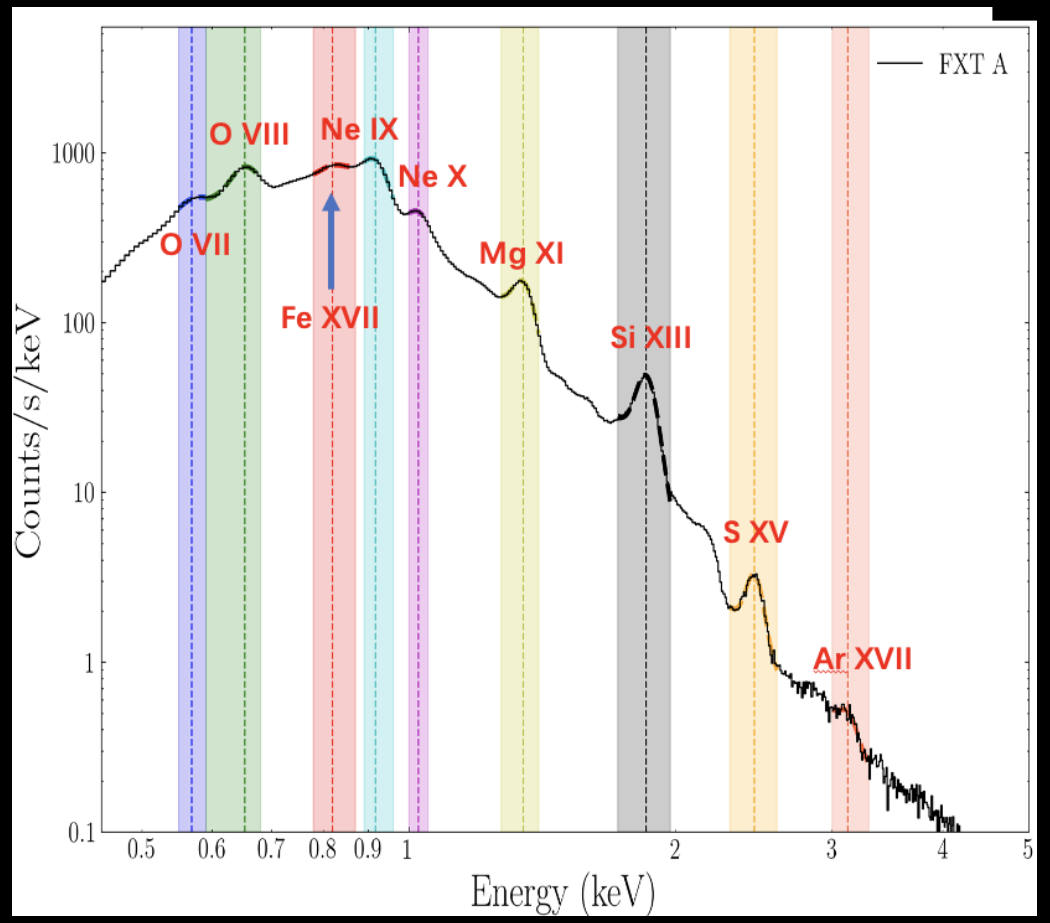


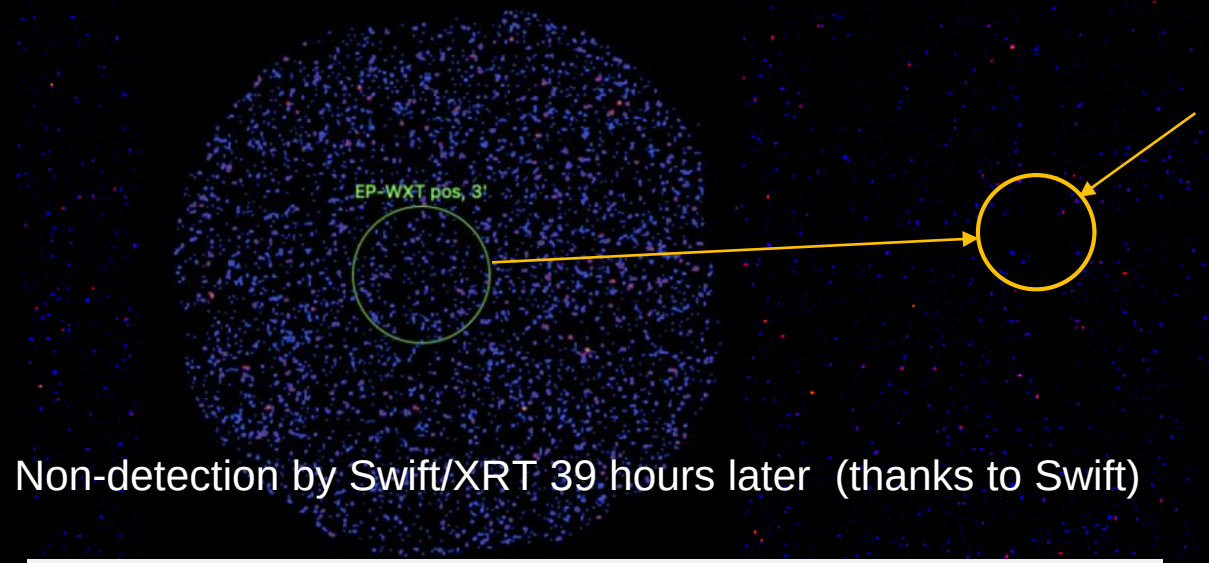
FXT 首光X-射线图像
FXT X-ray First light（0.3-10 keV）

船尾座 A 超新星遗迹（星云）
Puppis A supernova remnant (nebula)



FXT 同时获得的X 射线光谱
FXT X-ray spectrum obtained at the same time



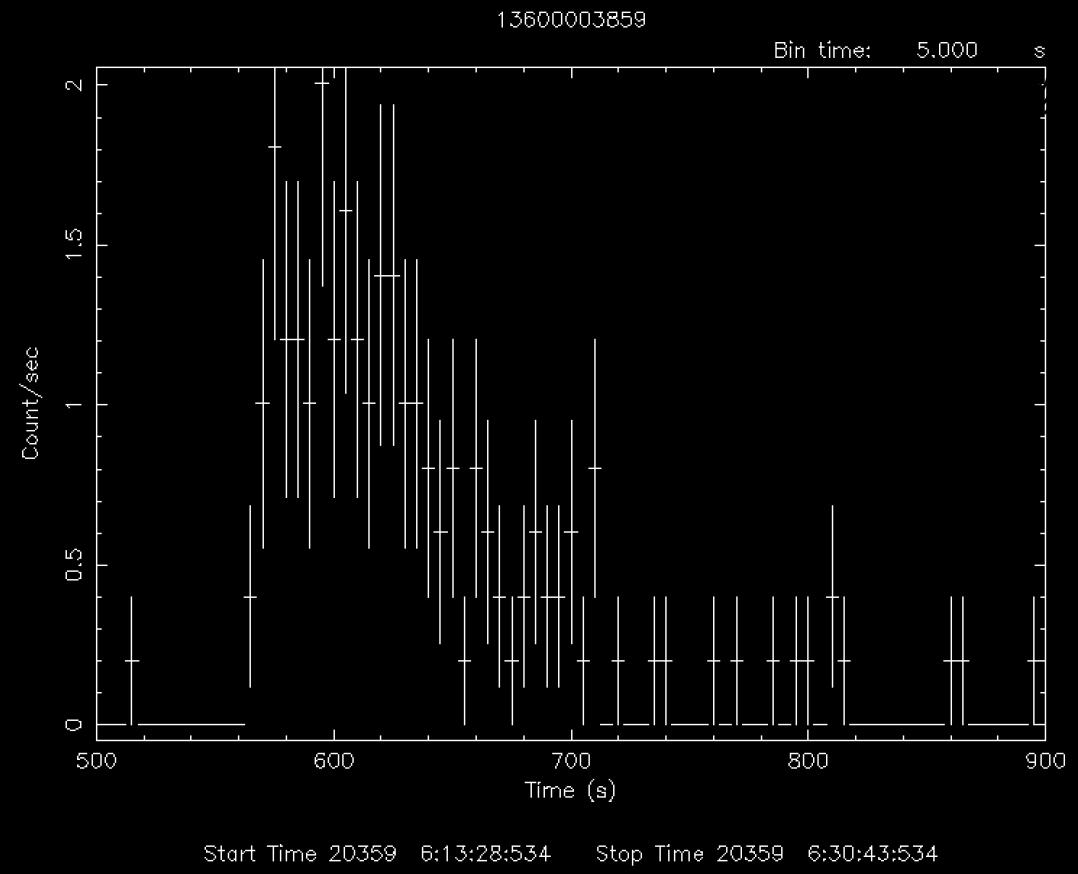


Non-detection by Swift/XRT 39 hours later (thanks to Swift)

EP240219a

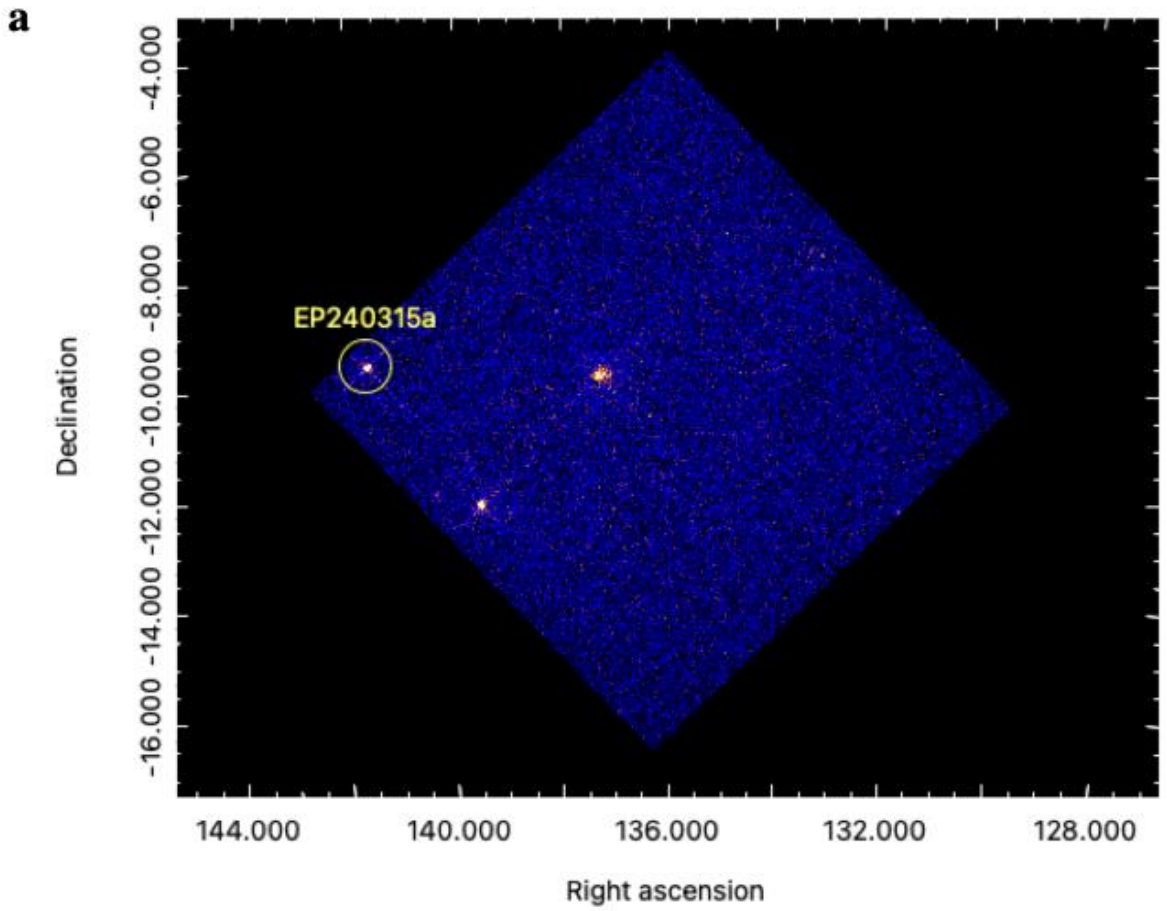
The first X-ray transient discovered by WXT on Feb 19, 2024, alert released on Astronomer's Telegram

- Duration < 200s
- Peak flux : 5e-9 erg/cm2/s (1/5 Crab nebula)
- Subthreshold GRB signal found in Fermi/GBM data (Zhang ATel #16473)
- Undetected by Swift/XRT 39 hours later
- Atel sent from EPSC: 1st EP alert!
- No optical counterpart found (starting T0+3days)

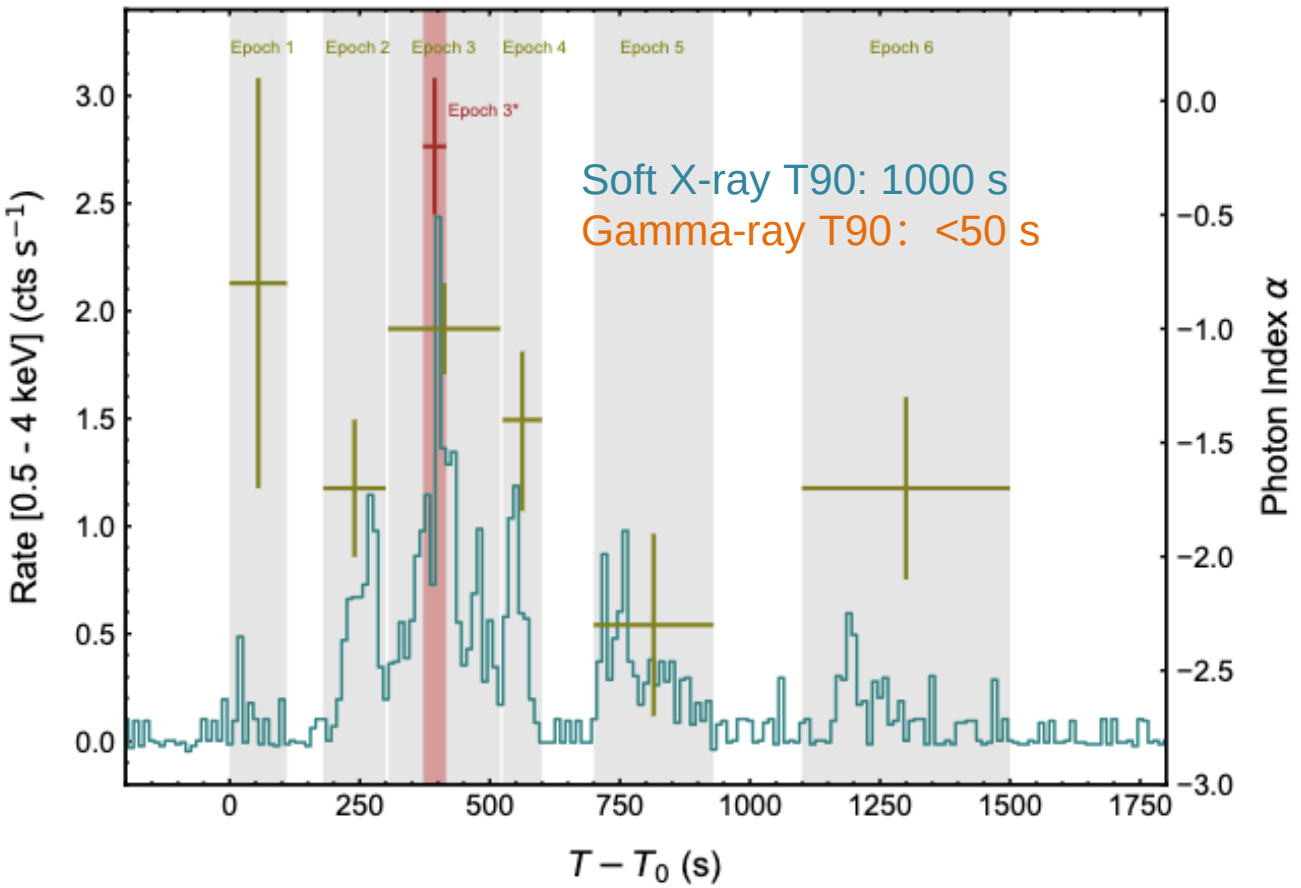


9.3° by 9.3 °, 1 time-frame = 33.3 sec

EP240315a: 1st transient with measured redshift



Onboard trigger, confirmed by on-ground analysis



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

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

EP240315a: 1st transient with redshift

- GCN 35931 *Einstein Probe detection of a fast X-ray transient EP240315a*

- GCN 35932 *ATLAS detection of a possible optical counterpart AT2024eju*

  Precise localization

- GCN 35936 *VLT/X-shooters pectroscopic z = 4.859*

  Redshift measurement

- GCN 35951 *EP-FXT detection of the X-ray afterglow*

  Very first X-ray follow-up observation

- GCN 35971 *GRB 240315C / X-ray transient EP240315a: Swift/BAT detection*
- GCN 35972 *Konus-Wind detection of GRB 240315C*

  GRB counterpart

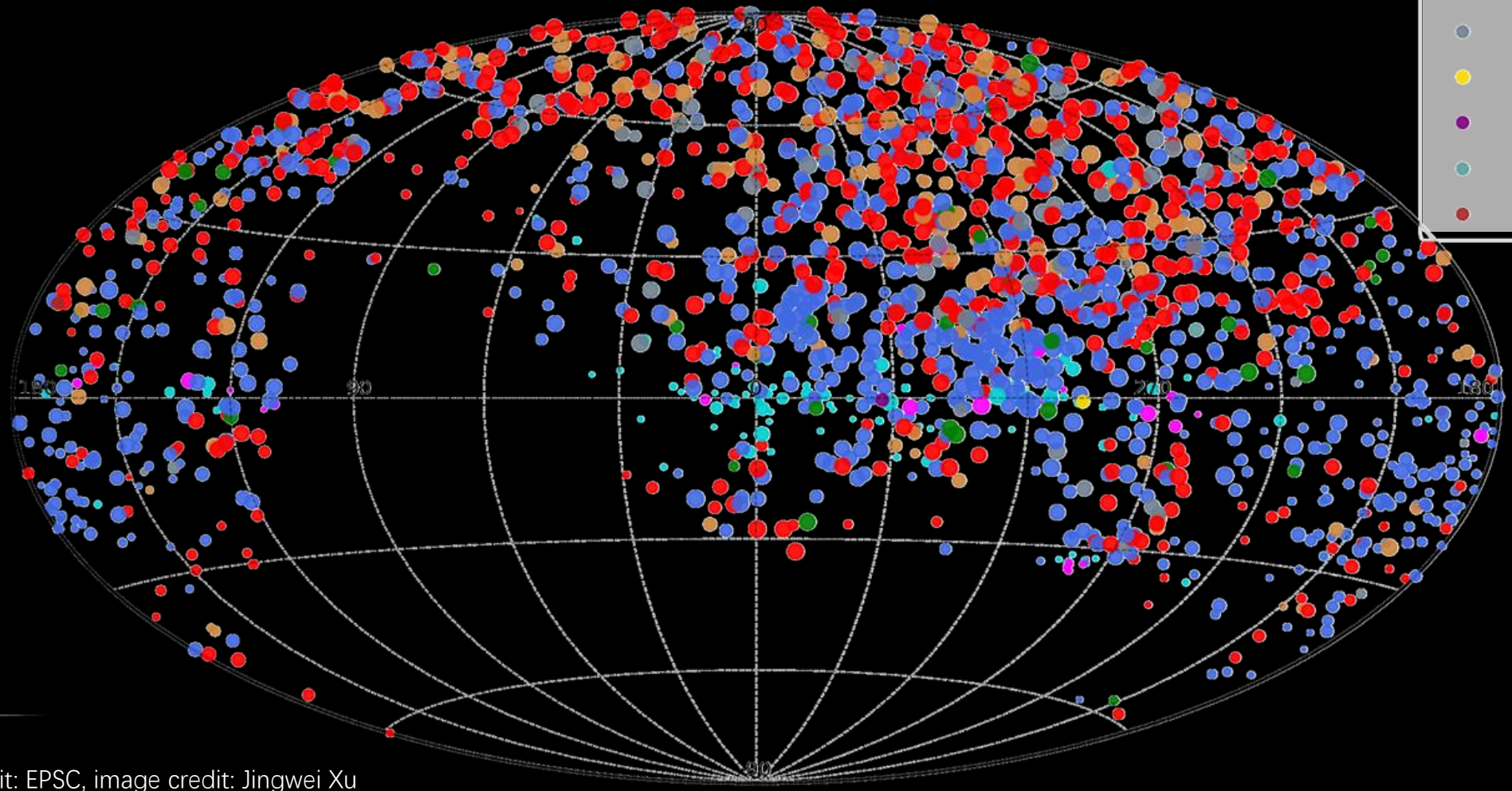
Gillanders J.H., et al. arXiv:2404.10660 (ATLAS optical/radio counterpart, z)
Levan A., et al. arXiv.2404.16350 (Stargate optical pho. and spec., z)
Liu Y., et al. arXiv:2404.16425 (jointly with Swift, Konus-Wind, Stargate teams)

WXT探测到的已知X-射线源：2100

WXT has detected known X-ray sources：2100

暂现源 transients：17 （亮 bright), ~100 （暗弱 faint）

恒星耀发 stellar flares：168



data credit: EPSC, image credit: Jingwei Xu

Summary

- EP has been in commissioning tests and calibration since launch on January 9
- Most in-orbit performance verifications have been completed
- Spacecraft & instruments working as expected
- Some issues/challenges yet to be resolved or improved
- > dozen fast X-ray transients (>100 faint ones) and other transients detected
- Formal science operations expected to start in June

http://ep.bao.ac.cn