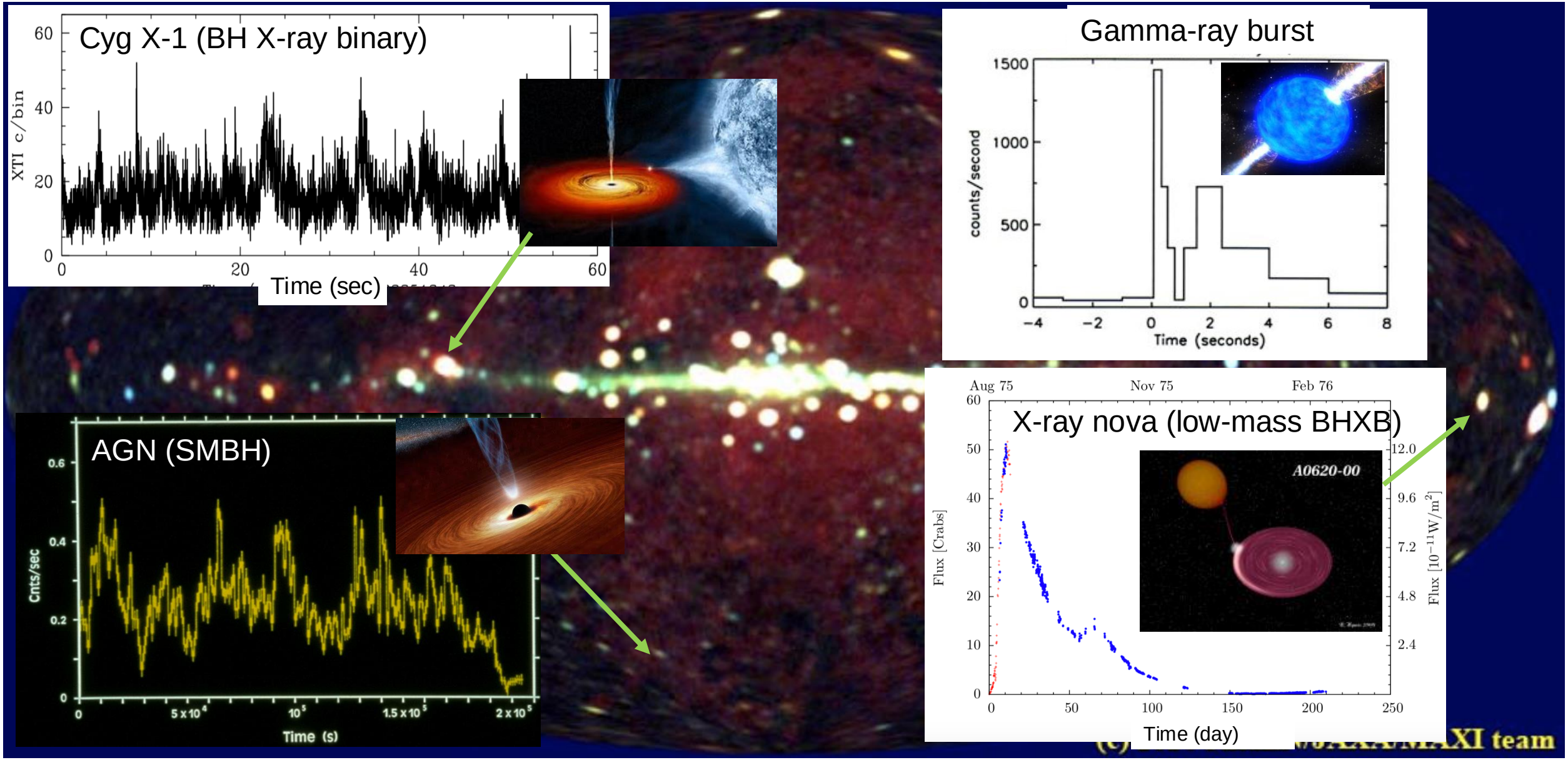
爱因斯坦探针（EP）实验及进展

袁为民

中科院 国家天文台

Image credit CAS/ESA

Variables & transients in X-ray sky



A rich history X/γ-ray wide-field monitors

bulk of extra-galactic X-ray transients

Very large space observatories or new technology

Detector area (cm^2)

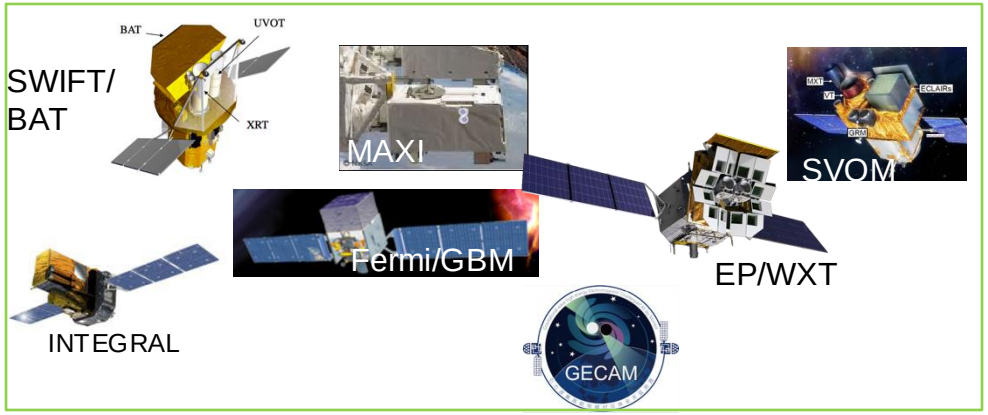
10^4

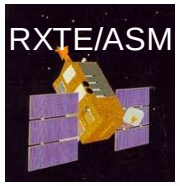
10^3

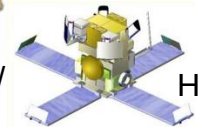
10^2

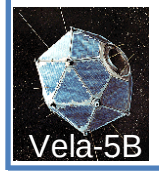
10^1

Galactic: mostly X-ray binaries
extra-galactic: mostly GRB









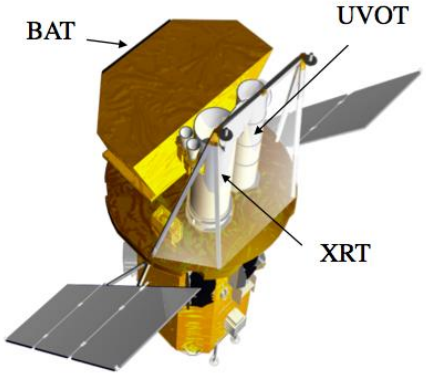
- Non-focusing: pinhole, coded-aperture
- Hard X-ray/γ-ray
- No dedicated transient-science mission

** incomplete list*

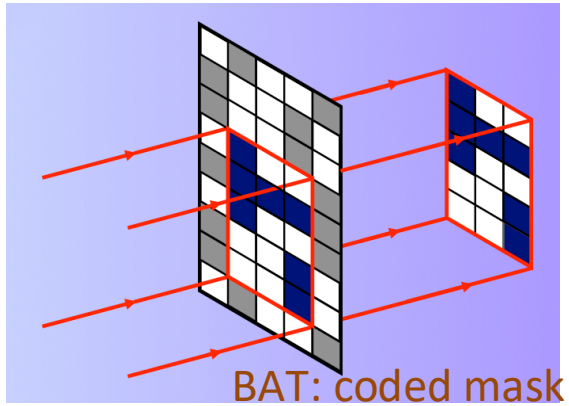
1970 1980 1990 2000 2010 2020 Year

Current X-ray wide-field monitors in orbit

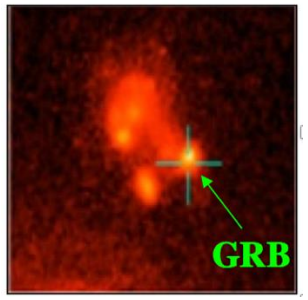
Swift (NASA 2004-)

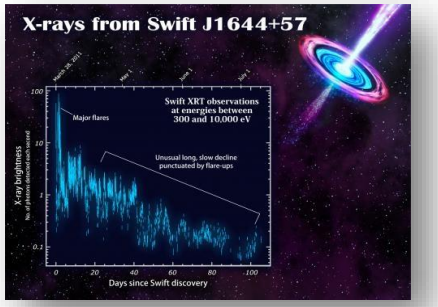


Credit: NSA/Gehrels

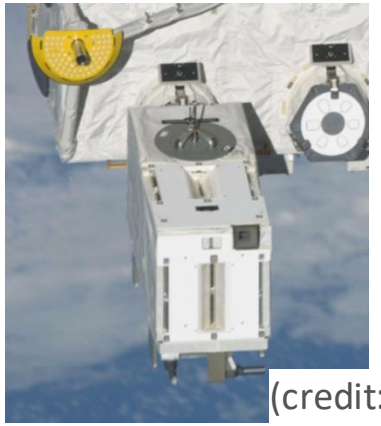


- GRB mission
- BAT: 14-300keV, FoV ~ 2 sr
- 2 GRB + 0.5 transients per week



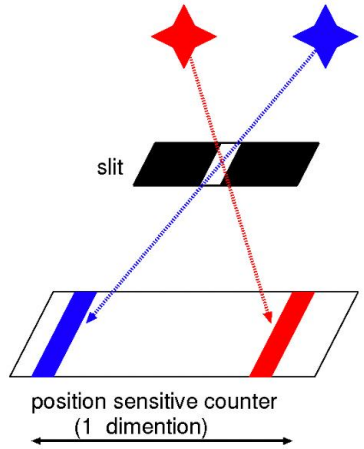


MAXI on ISS (JAXA 2009-)

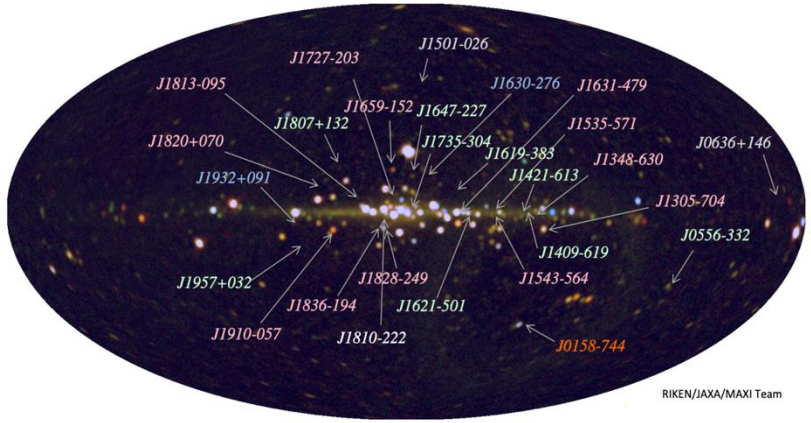


(credit: RIKEN/JAXA)

pinhole/slit camera



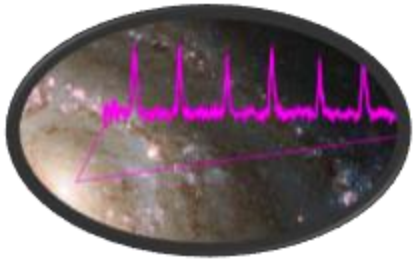
- 0.8 Transients per week (mostly Galactic)
- Monitoring large number of sources hourly/daily



New high-energy transients & science questions

BH tidal disruption event

Demography of Black holes
How matter falls onto BH?
How jets form?



Quasi-periodic eruption

EMRI as GW sources?

High-redshift GRB

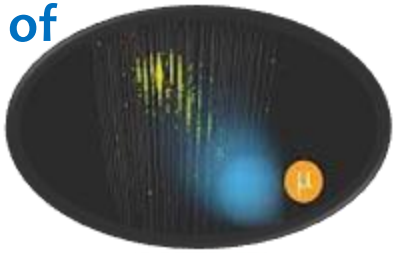
When first stars formed?
metal enrichment in early universe

Next generation X-ray monitors needed to see

- **deeper/further**
- **High cadence**

EM counterpart of neutrino events

How particles Accelerated?



Supernova shock breakout

Supernova physics & progenitors

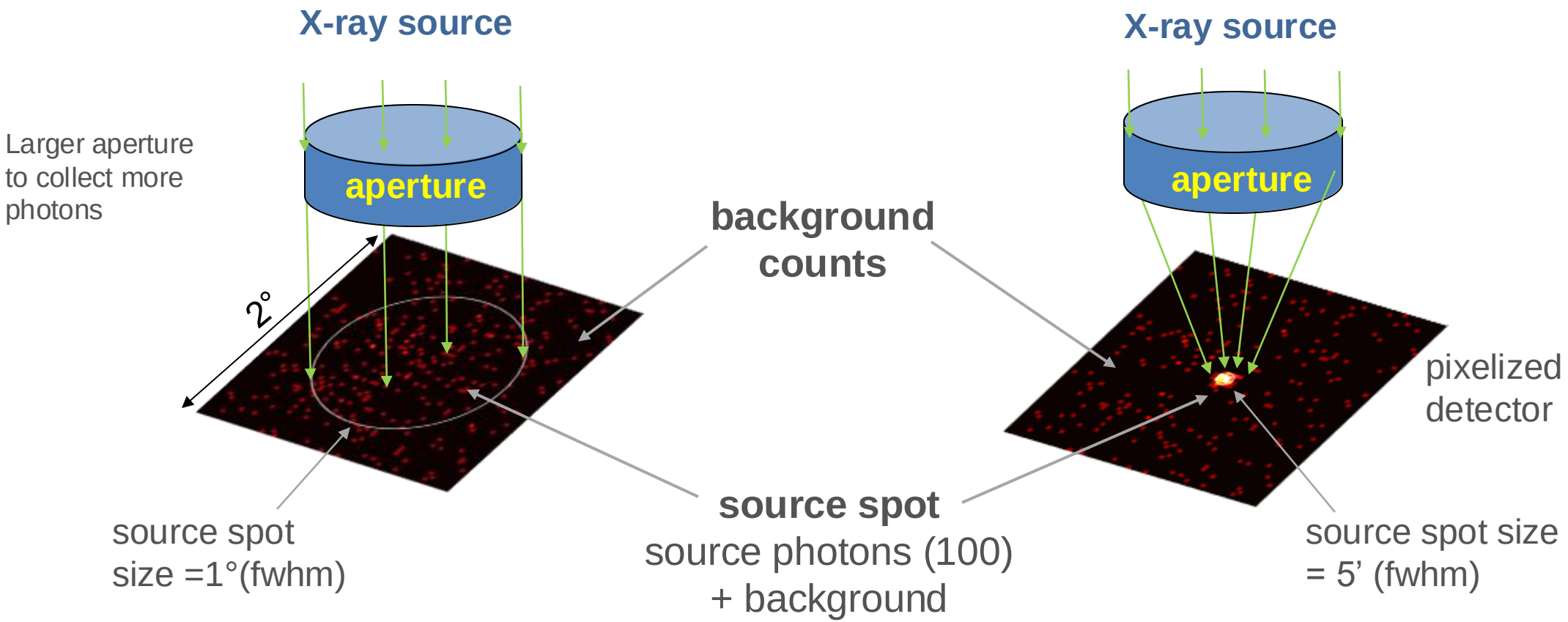
EM counterpart of gravitational waves

What are EM counterparts?
How compact objects merge?

How X-ray focusing imaging improves sensitivity

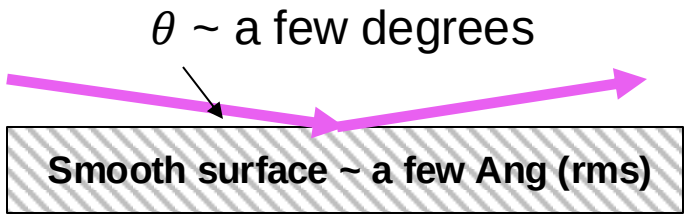
non-focusing

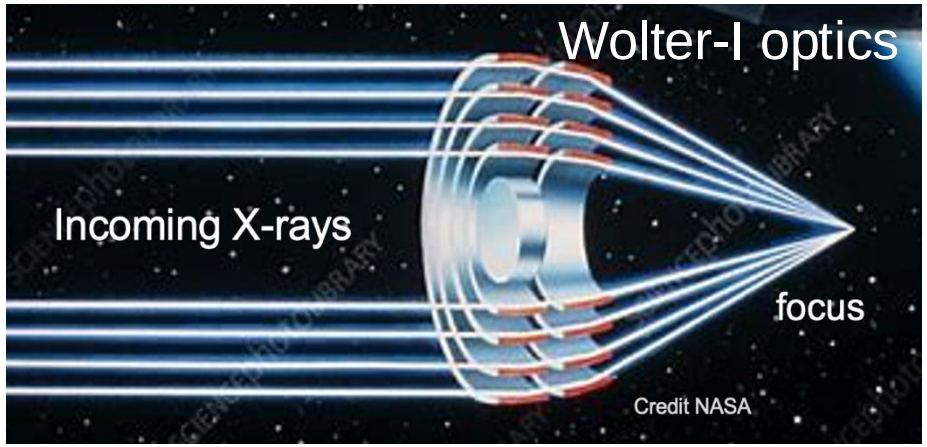
focusing imaging



X-ray focusing imaging: Wolter-I optics

- X-ray reflection by grazing incidence
- Higher reflectivity for lower-E X-rays





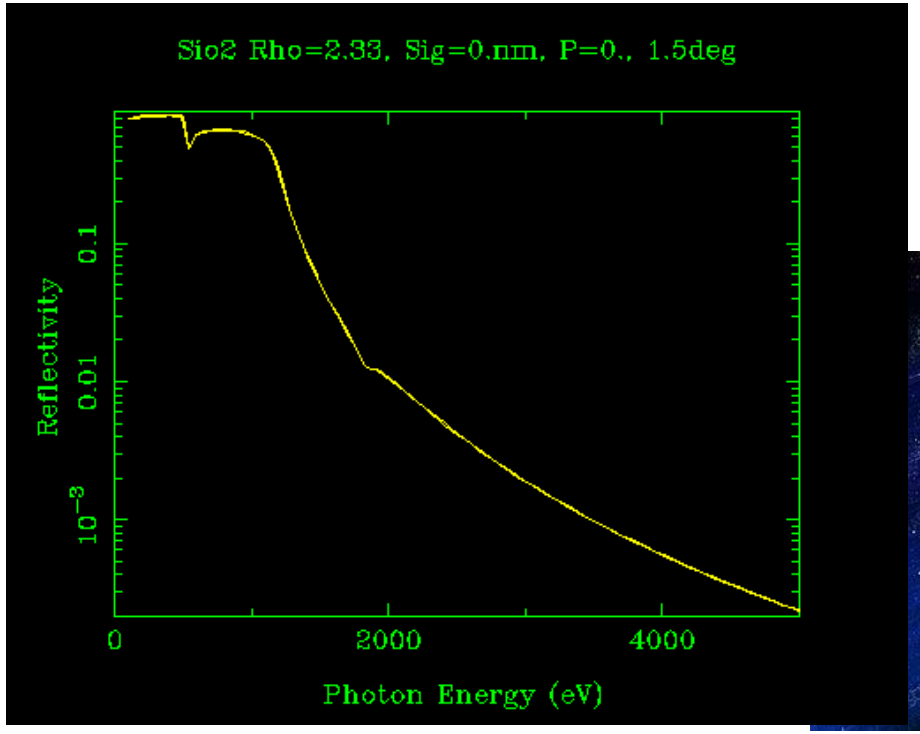
high sensitivity

small FoV (< 1-2 deg)

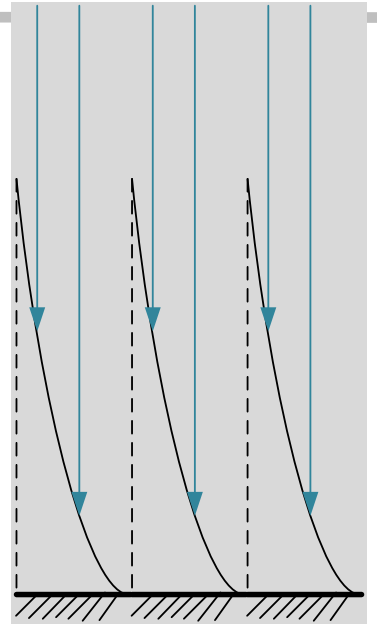
Frist: Einstein Observatory (NASA) 1978-1981

100 x more sensitive than Uhuru

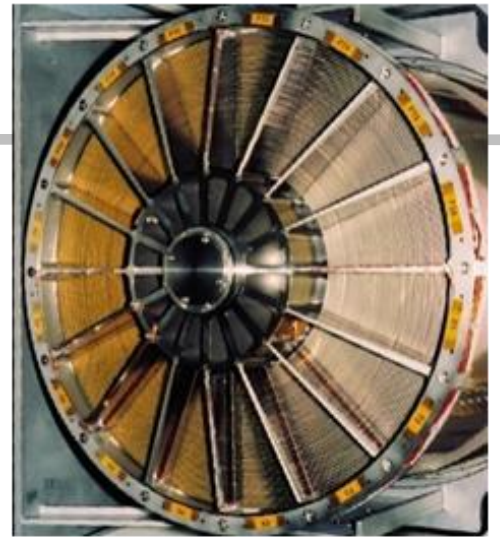
Revolutionzied X-ray astronomy



XMM-Newton, Chandra, NuSTAR, eROSITA…

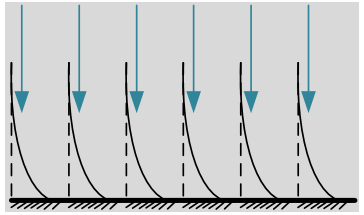


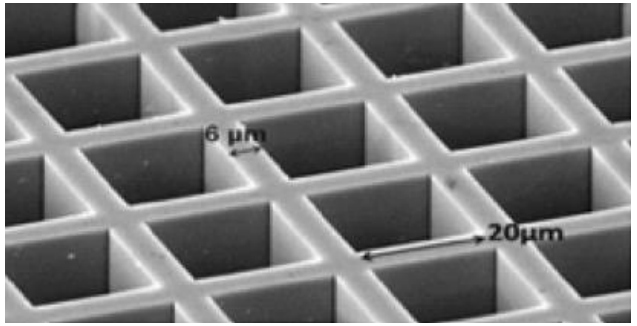
~200 mm spacing
>10 mm thickness
~1000 mm height



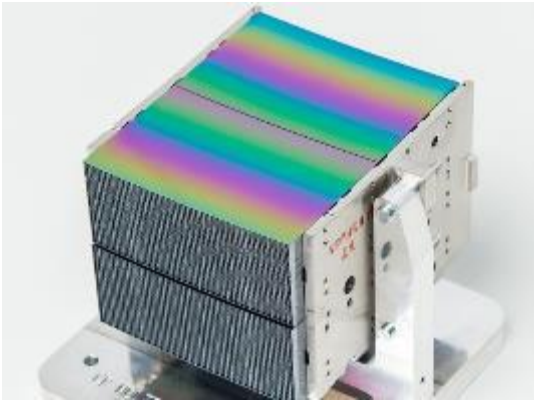
~6 mm spacing
~1 mm thickness

Layers
axisymmetric





~0.04 mm spacing
~0.008 mm thickness
~2 mm height

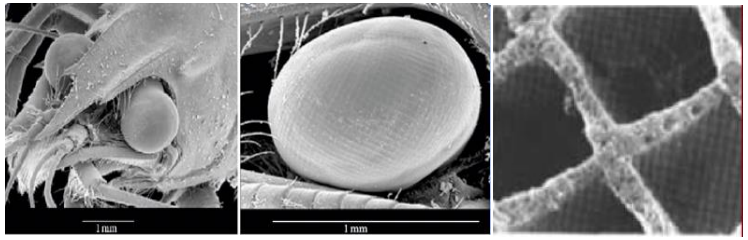


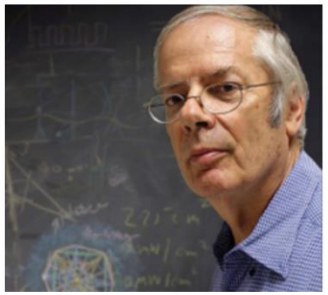
Layers
orthogonal

The key issue of X-ray optics: How to configure the reflective surfaces less than nm roughness in arcsec accuracy.

Lobster-eye optics for X-ray focusing imaging

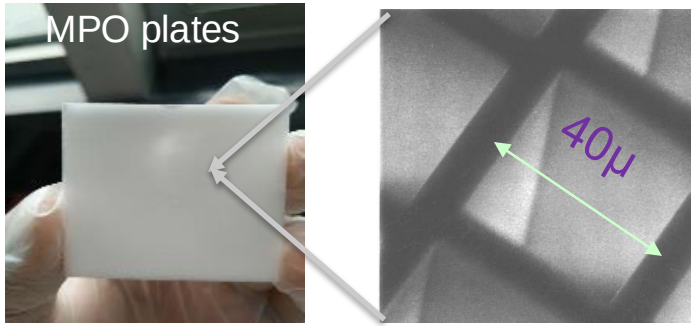
grazing incidence reflection by Lobster-eye Micro-Pore Optics (MPO)

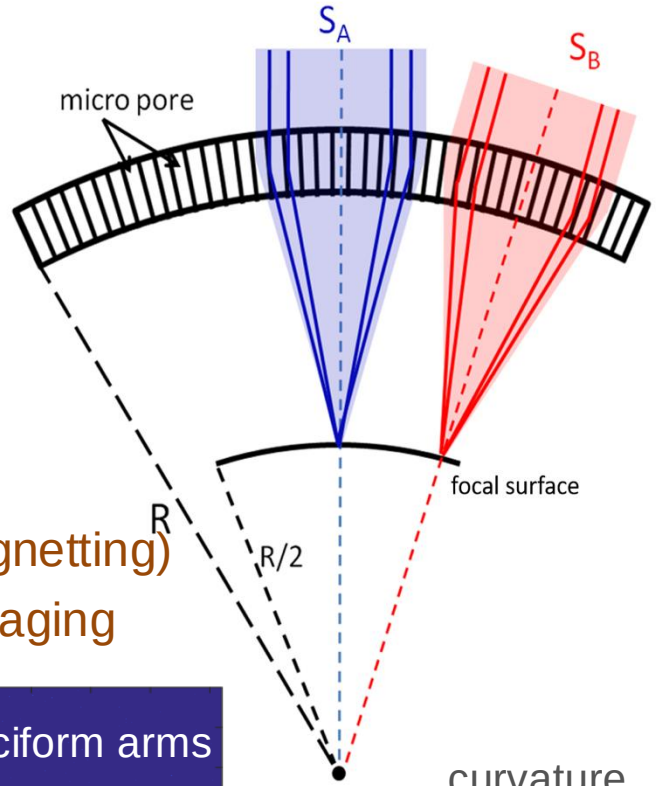




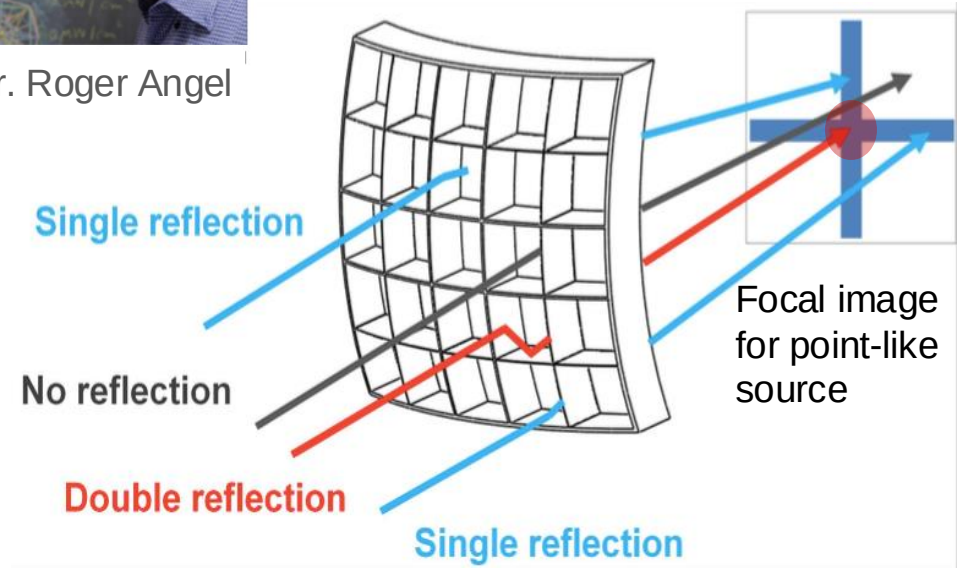
Dr. Roger Angel

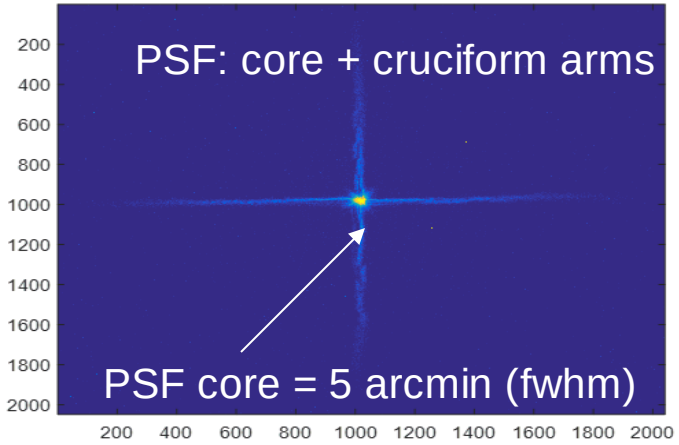
image credit:
http://www.as.utexas.edu/lectures/great_lecture_twenty.html





- Wide FoV (no vignetting)
- True focusing imaging





measured X-ray PSF mage @XIL/NAO/CAS

A real data from an observation of WXT

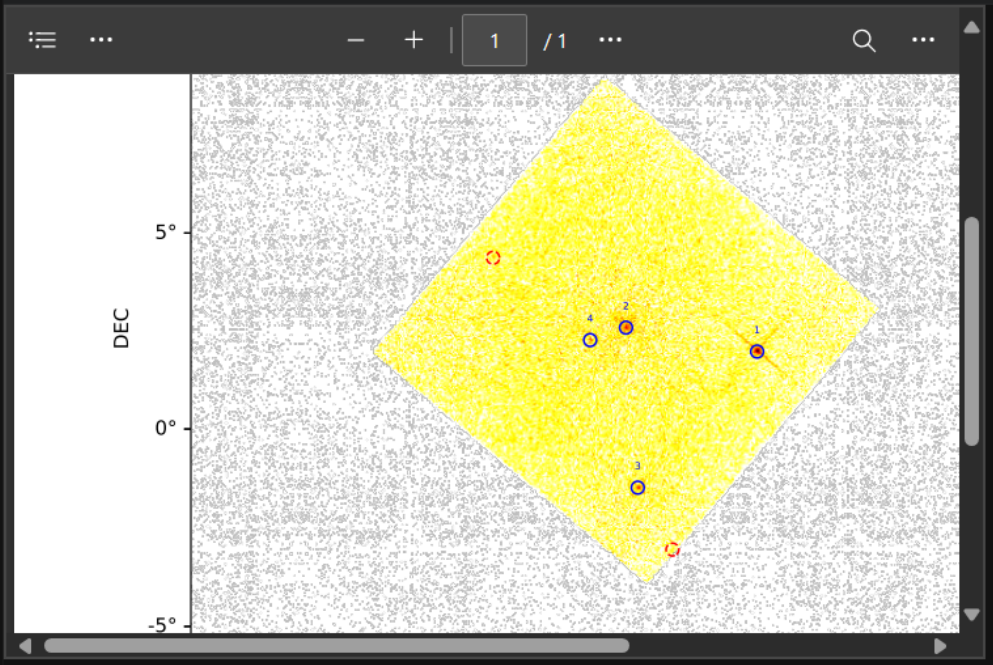
ep08500000058wxt11s1 v7

RA, Dec	187.616, 2.012
RA (HMS), Dec (DMS)	12h30m28.0s , +02d00m44.2s
Galactic l, b	290.736, 64.386
1 σ Pos Err (arcmin)	0.232
Exposure Time (s)	24838
Observation Start (UTC)	2024-04-10 12:35:55
Net Rate	0.02039278
Estimated Flux (erg/cm^2/s)	4.08e-11
Counts	506.51584
Background Counts	6.405128
Significance	31.42956
Source Detected Number	148 WXT
Observation Number	57 WXT, 6 FXT

Open an issue in Redmine

Issues of related observation

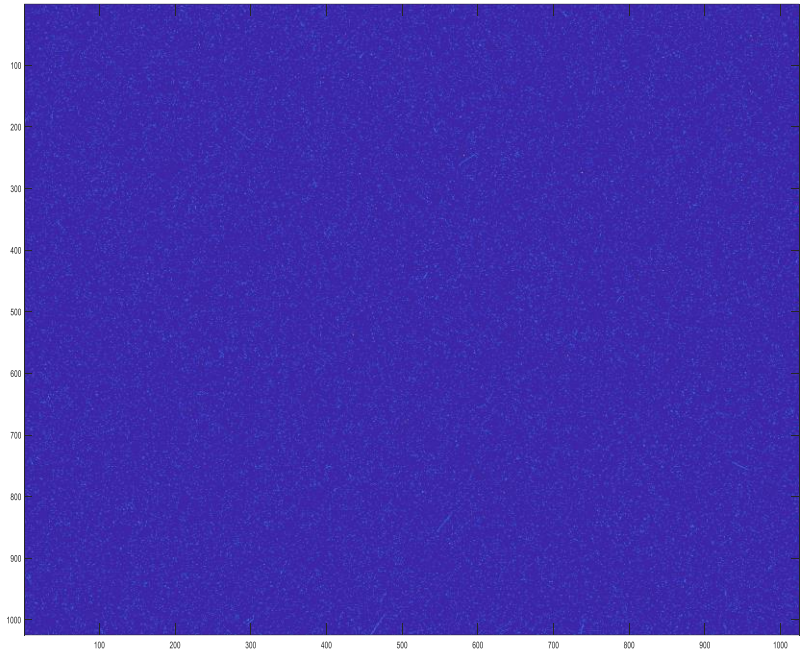
Source QuickLook

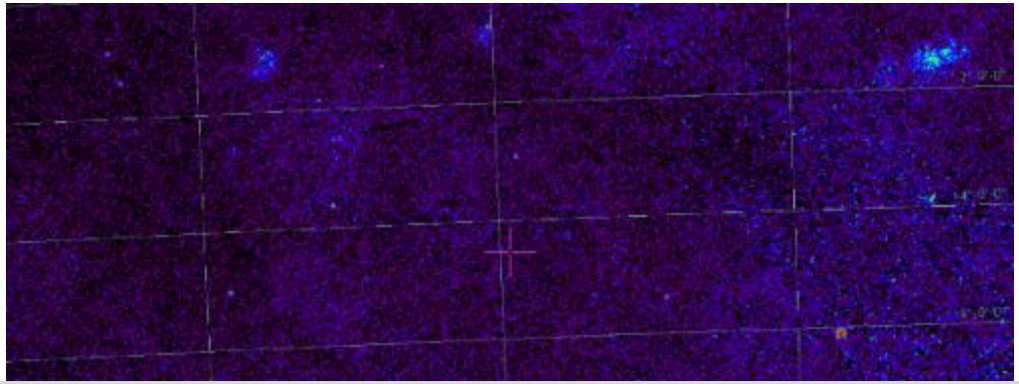


Show image in DS9 | Download level1 data | Download Level2-3 Data

Identify a source signal from background

Even on ground 0.04 cnt/sec/cm^2





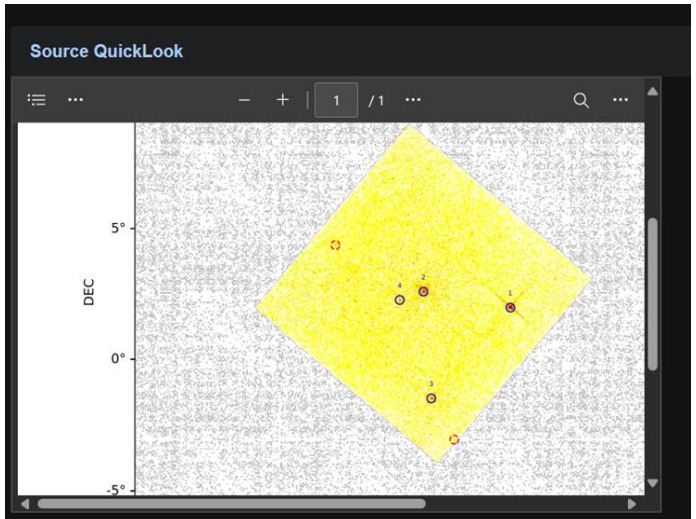
Charged particles, Defused X-ray, foreground…

表 1. 根据轨道号 06800002000 至 06800003000 的数据，得到的 LEIA 本底计数率表。

cmos	Count rates in different energy ranges (cts/sec/cm^2)					-
	0.5-4 keV	0.5-1 keV	1-2 keV	2-3 keV	3-4 keV	orbits available
13	0.31	0.07	0.07	0.07	0.06	660
14	0.31	0.07	0.08	0.07	0.07	618
15	0.32	0.09	0.10	0.09	0.09	479
16	0.36	0.08	0.09	0.08	0.08	546

In 25 ksec integration:

- 25k*36*0.31=27000 in space
- 25k*36*0.04=3500 on ground
- 506 Source counts



微孔龙虾眼聚焦成像光学及X 射线探测器技术研发 @国家天文台

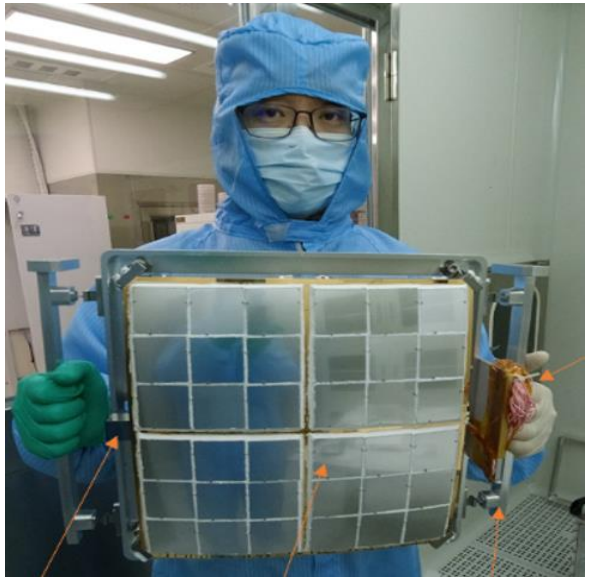
2010, 国台 X 射线成像实验室成立

(由高能所张双南研究员建立并任实验室首席研究员)

张臣博士 领导开展微孔龙虾眼聚焦成像光学技术的研发

微孔龙虾眼成像技术研发
负责人 张臣

X-ray beam line （17m）@NAOC/X



WXT 聚焦镜组件 (NAOC/CAS)

CMOS detectors
@SITP/CAS

Einstein Probe (EP) mission

Goals time-domain astronomy

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

Milestones

- Lobster-eye R&D @ XIL/NAO since 2010
- Mission concept proposed 2012
- **Adoption** 2017/12
- Joined by **ESA & MPE** 2018, **CNES** 2022
- Pathfinder ***LEIA*** launched 2022/07
- **Launch** Jan. 9 2024
- Lifetime: 3 yr, goal 5 yr

EP Instruments & spacecraft

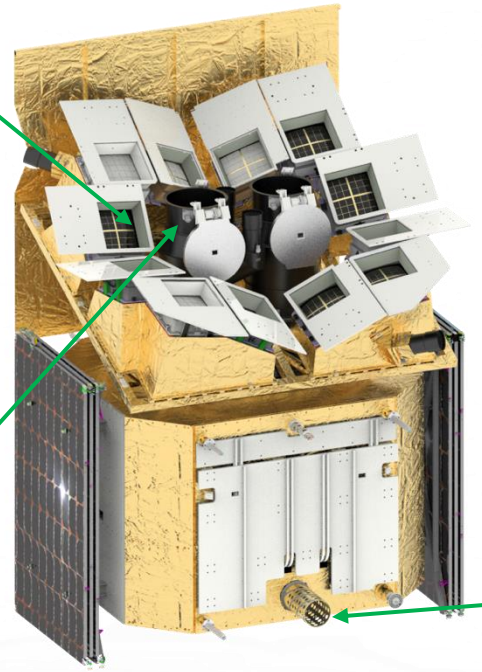
Wide-field X-ray Telescope
WXT (12 modules)

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) 风行天

Wolter-1 + pn-CCD
FoV: 1 deg
Band: 0.3 -10keV
Resolution: 24" (HPD, on-axis)
Effe. area: ~300 cm^2 @1keV (x 2 units)

- 首次大规模采用X 射线 '微孔聚焦成像' 技术
- 首次采用CMOS探测器进行空间X射线天文探测
- 看得更远、更暗、更精



Spacecraf

星上暂现源自动搜寻、卫星快速机动指向、自主后随观测、警报信息快速下传

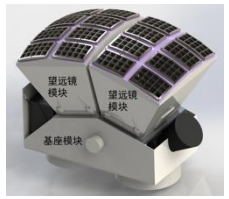
Telemetry

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

中国主导的国际合作：欧空局、德国马普所、法宇航

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

艰苦历程：十年磨一剑 2013.1 – 2023.12



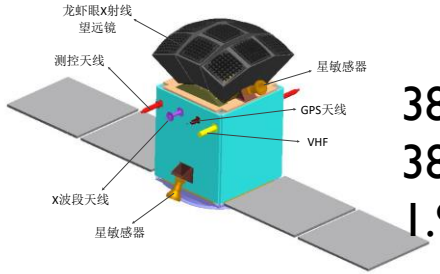
中国空间站 X 射线全天监视器 XASM

2010
X射线成像实验室 XIL 高能天体物理组

2011
XASM 项目论证

2012
XASM 项目建议书

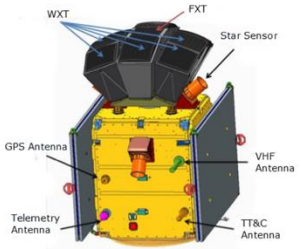
2012
提出EP项目



380kg
380W
1.9米

2013.01
提交EP项目建议书，并入选背景型号

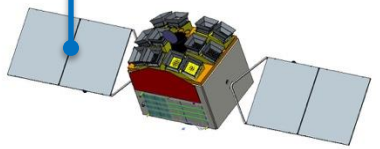
2014-2016
EP背景型号研制



2015
EP通过遴选，成为中科院先导重点支持项目之一

采用 CMOS

2017.12
EP卫星正式通过工程立项



单 FXT 设计

2018
ESA、MPE加入

2020.07
EP卫星系统进入初样研制

2022.03
EP卫星系统进入正样研制

2022.07
LEIA 发射

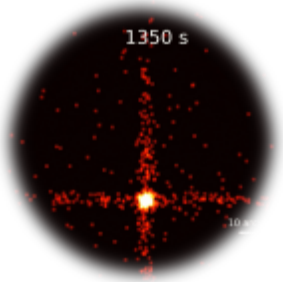
2022
cnes 加入

~1400kg
~1400W
> 3米

2023.08
EP卫星出厂

2023年底
择机发射

EP 核心科学目标



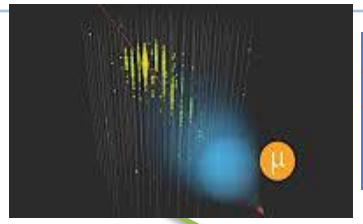
以最高探测灵敏度、系统性发现宇宙X射线暂现和剧变天体，监测天体活动性

通过捕捉 X 射线耀发，发现和探索宇宙中沉寂的黑洞和其它致密天体

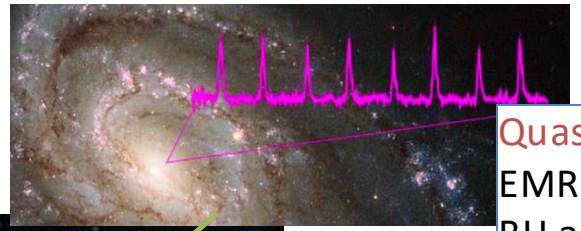
探寻伴随引力波事件的X射线源并精确定位、增进对致密天体并合过程的理解

Various classes of high-E transients & variability

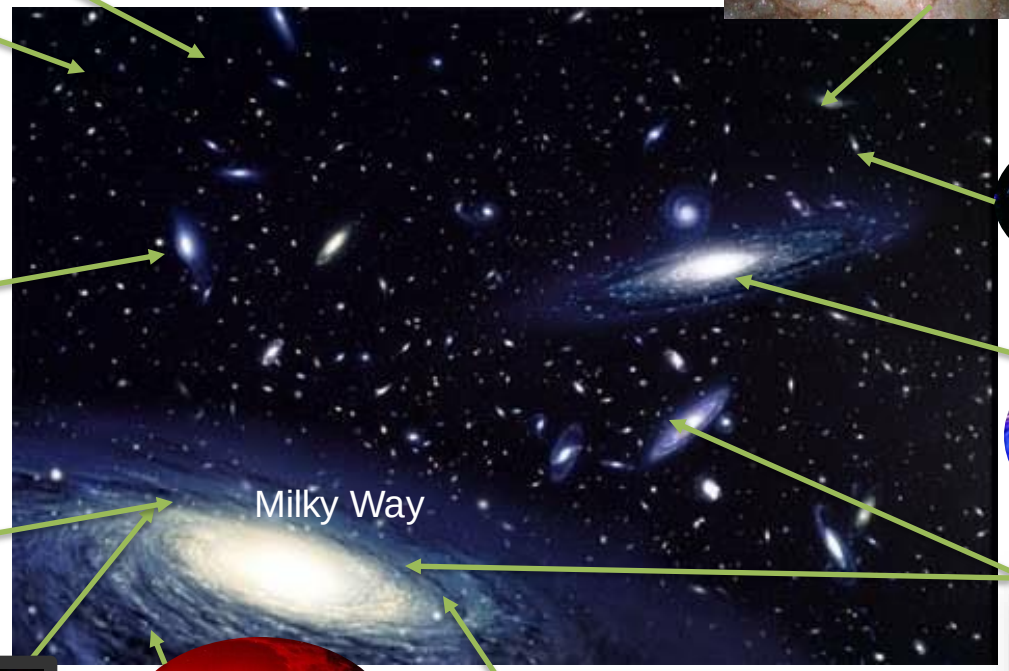
X-ray flash & LL GRB
GRB physics



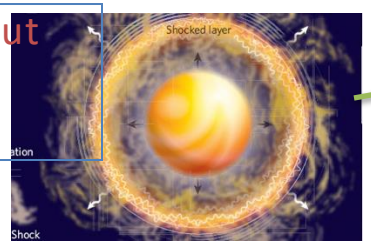
X-ray flares associated with neutrino events
particle acceleration



Quasi-periodic erruption
EMRI (GW source?)
BH accretion ?

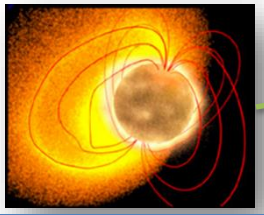


SN shock breakout
SN physics
progenitors



Active galactic nuclei
Extreme gravity, BH accretion/jets/growth

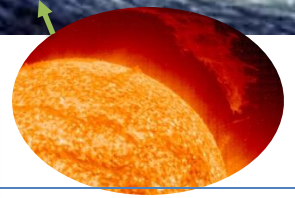
Intermediate-mass BH
BH physics/accretion



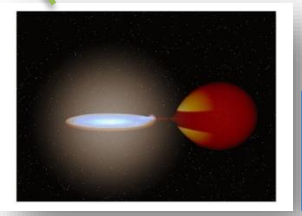
magnetar
extreme magnetic Field

BH X-ray binary
Extreme gravity
BH physics/accretion

Fast Radio Burst
X-ray sources



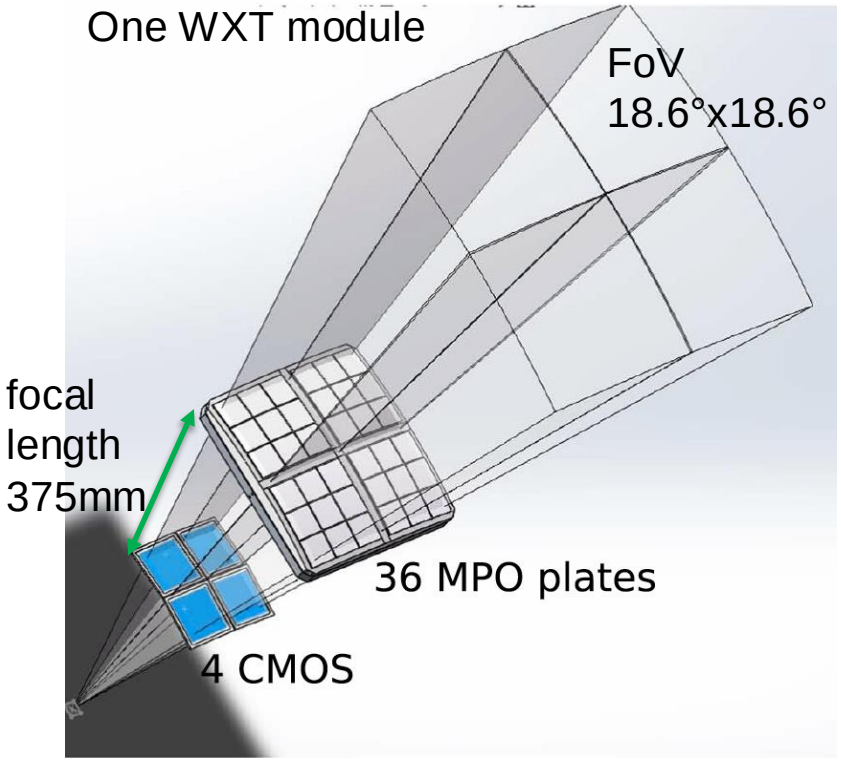
Star X-ray flares
Magnetic fields
Corona activity



Thermal nuclear burst
Neutron stars physics

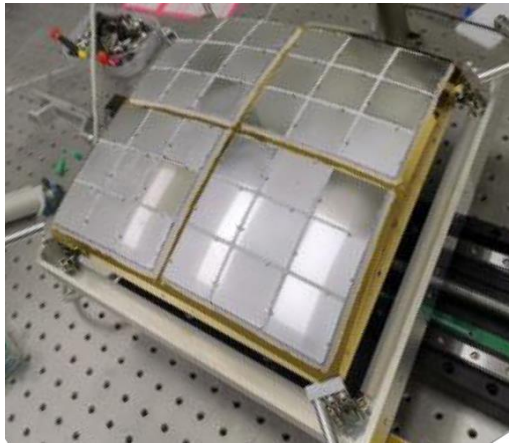
Wide-field X-ray Telescope (WXT)

Lobster-eye imaging system



Zhang et al. 2022 ApJL, 941, L2

mirror assembly (1 module)



MPO plates (developed by NNVT jointly with NAO/CAS)

41mm **x 41mm** each

In total

432 MPO plates

48 CMOS (1728 cm^2)

possibly the largest focal detector array for X-ray focusing imaging telescopes

detector array (1 module)

BI CMOS sensors optimised for X-ray

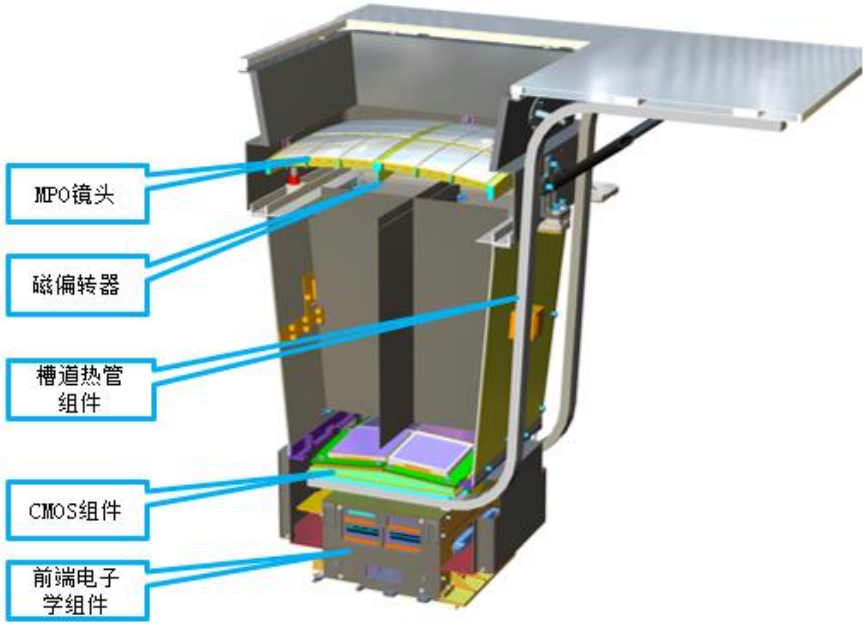
4 6cm x 6cm (4kx4k)

Time resolution 50ms

ΔE ~ 122eV @1.25keV

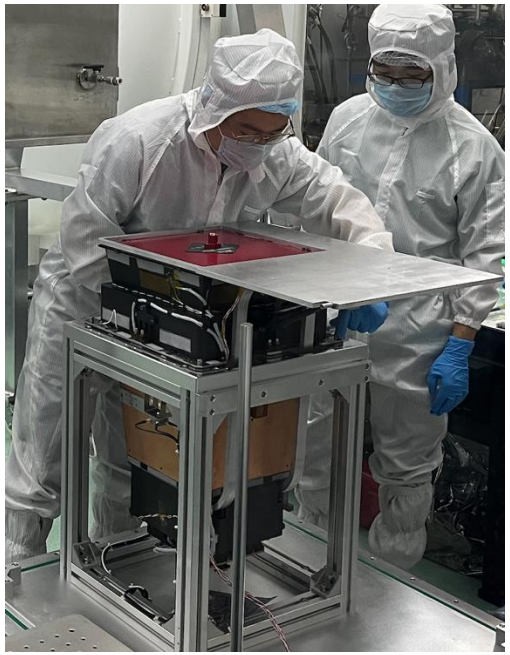
Wide-field X-ray Telescope

one WXT module



Flight model

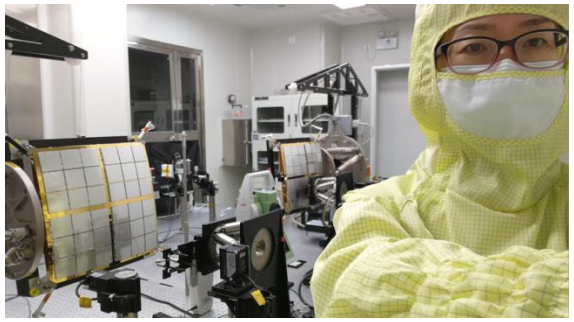
Weight 17kg



Lead of LE mirrors
Chen Zhang (NAO/CAS)

Instrument scientist
Zhxing Ling (NAO/CAS)

WXT chief designer
Xiaojin Sun (SITP/CAS)



MA engineer
Yanfeng Dai (NAO)

中国科学院上海技术物理研究所
SHANGHAI INSTITUTE OF TECHNICAL PHYSICS, CHINESE ACADEMY OF SCIENCES

中国科学院国家天文台
NATIONAL ASTRONOMICAL OBSERVATORIES, CAS

esa

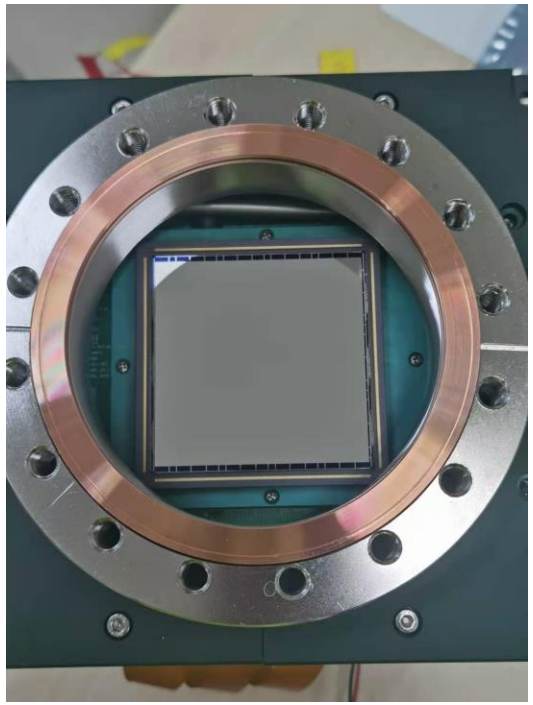
中国兵器工业集团 北方夜视技术股份有限公司
NORINCO GROUP NORTH NIGHT VISION TECHNOLOGY CO.,LTD

中国科学院电工研究所
INSTITUTE OF ELECTRICAL ENGINEERING, CHINESE ACADEMY OF SCIENCES

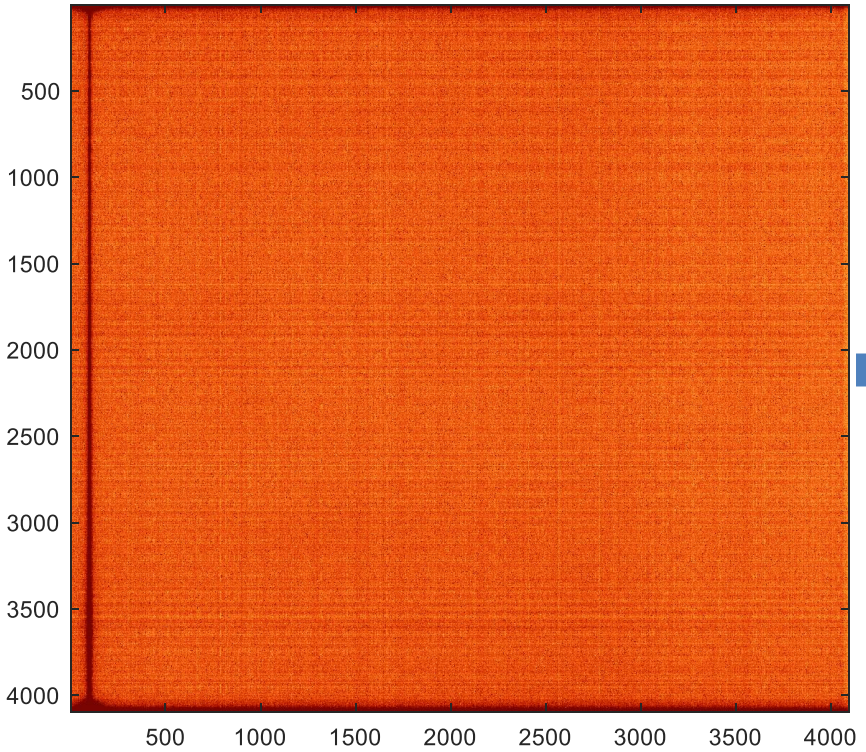
Nssc 中国科学院国家空间科学中心
National Space Science Center, CAS

CMOS Sensor

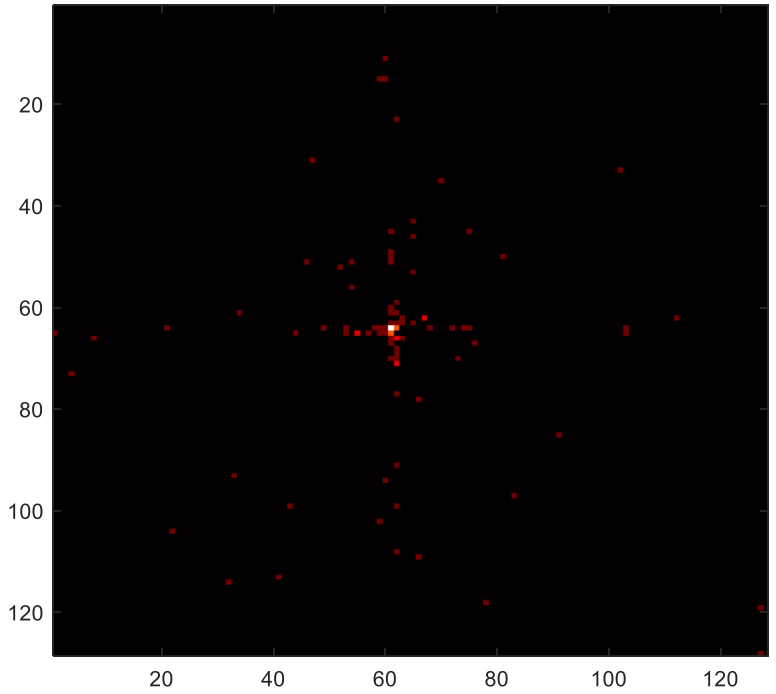
- 16 million pixel array *20 frame/sec*48 cmos
- The X-ray events：~20 /s/cmos
- Need to handle 15 billion pixels/sec to obtain about 1000 events/sec
- Efficient and reliable operation for 3600*24*365*5 secs



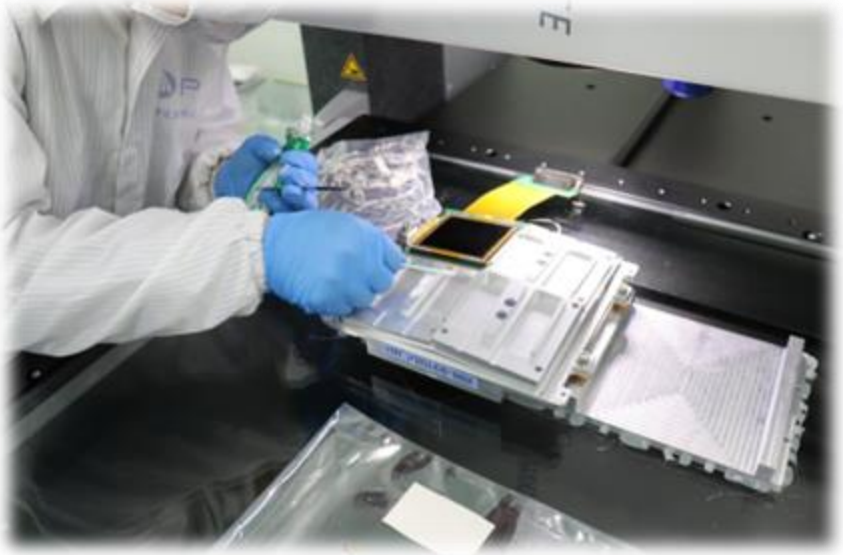
Raw：16 million

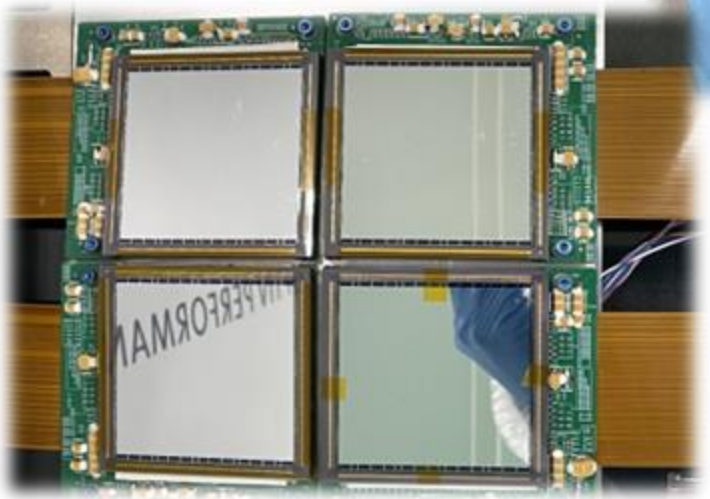


90 events (ground test)



The AIT of WXT

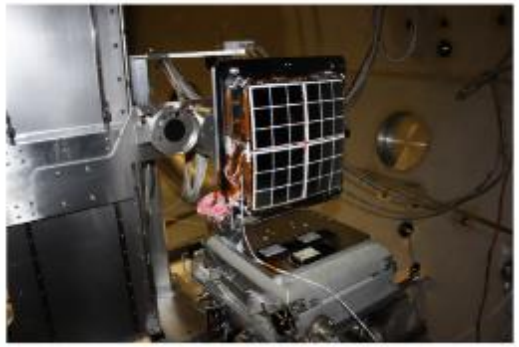


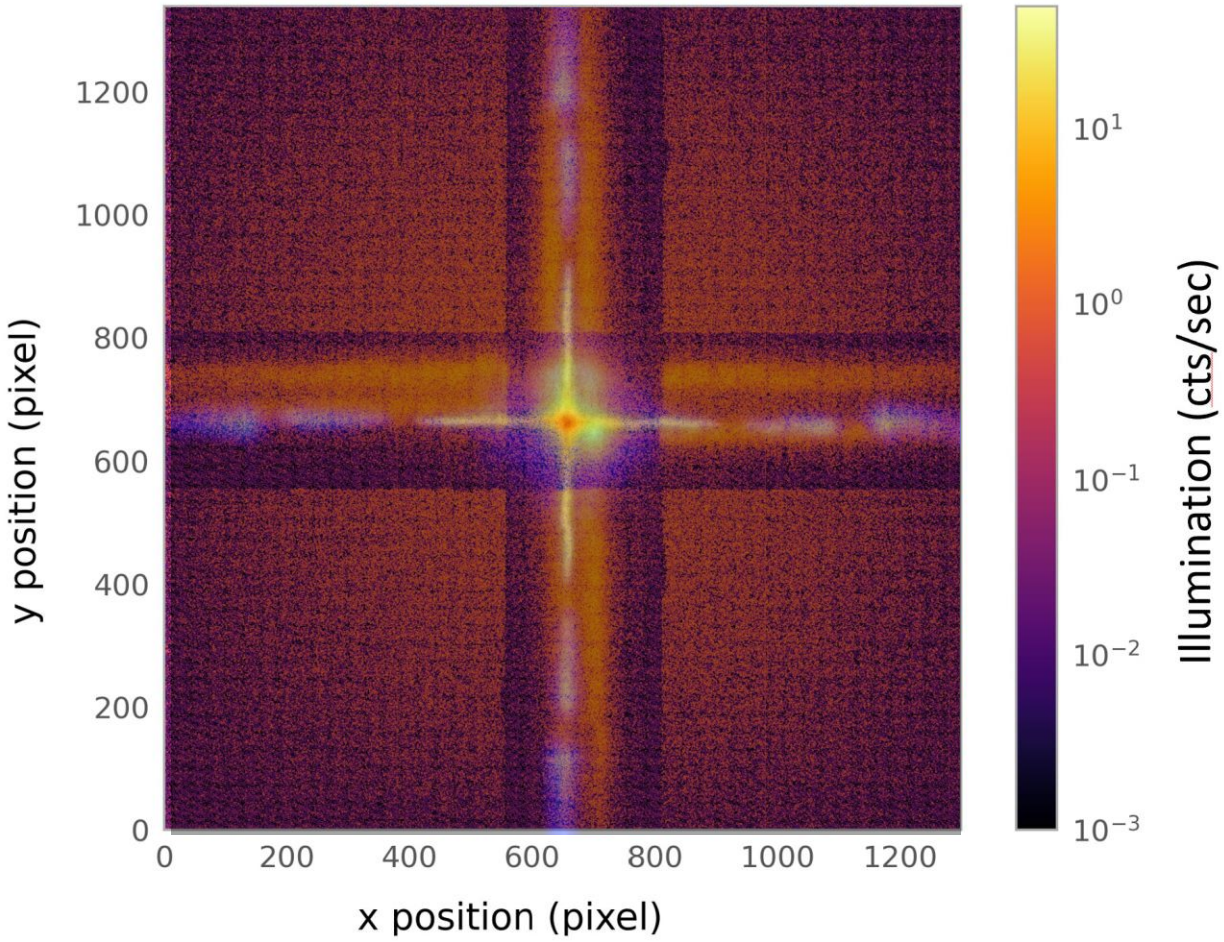


WXT in operation in vacuum

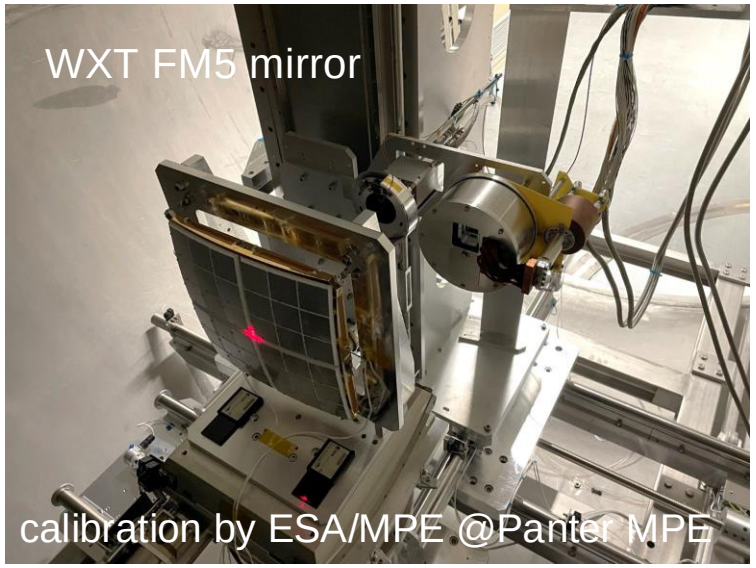
The state-of-art lobster-eye optics

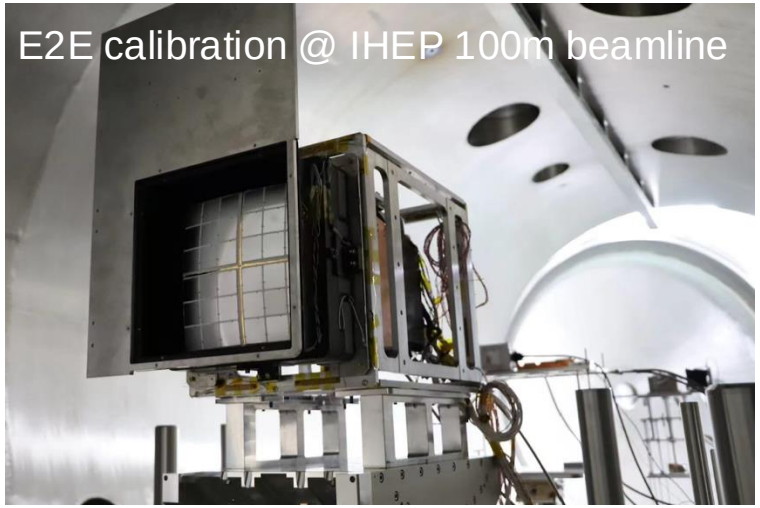
VS

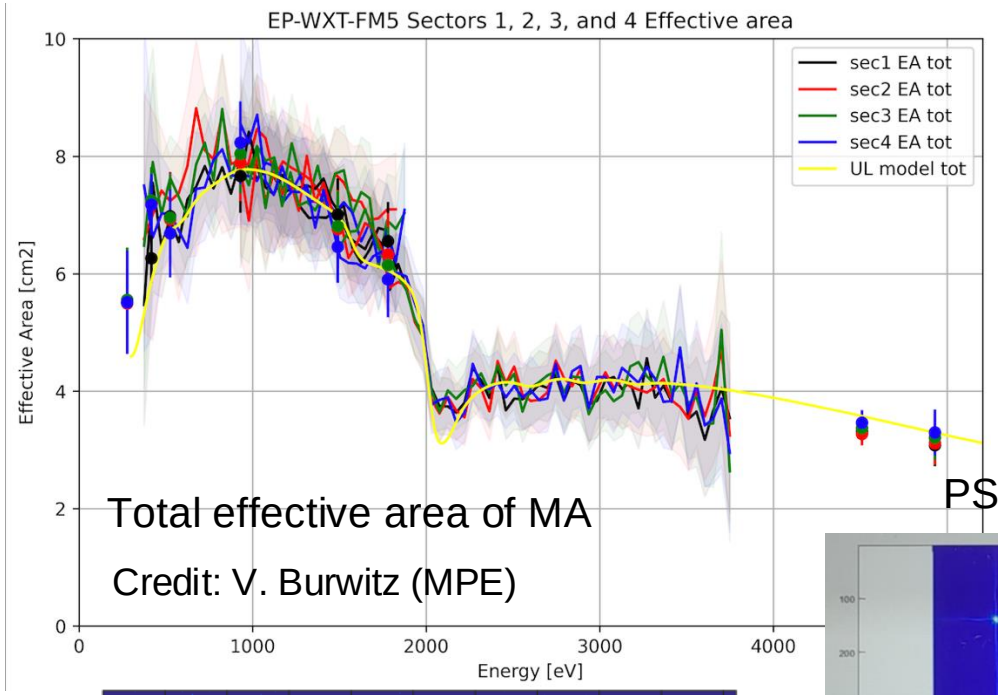


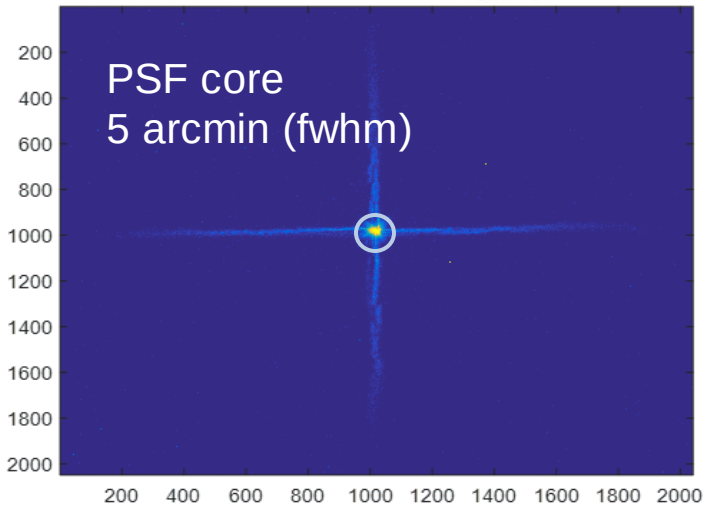


WXT on-ground calibration



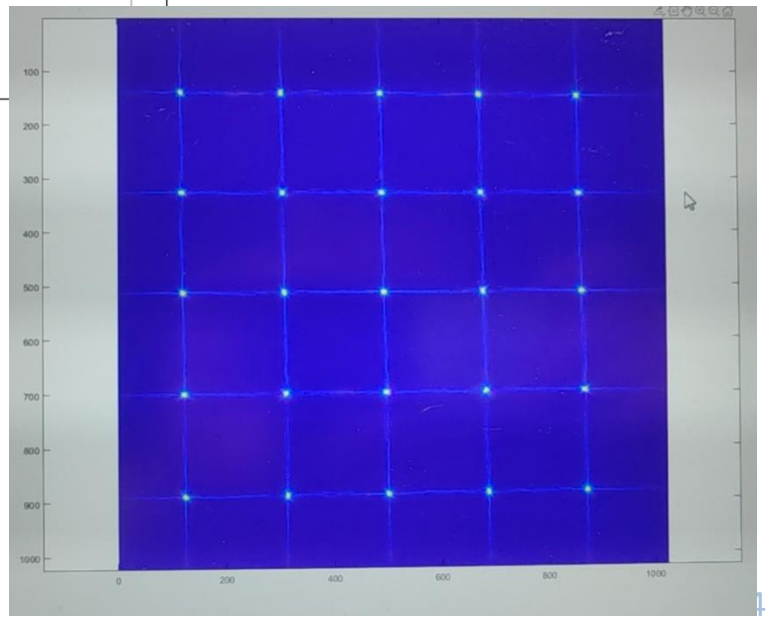






¼ FoV (9 deg x 9 deg)
of one module (FM)

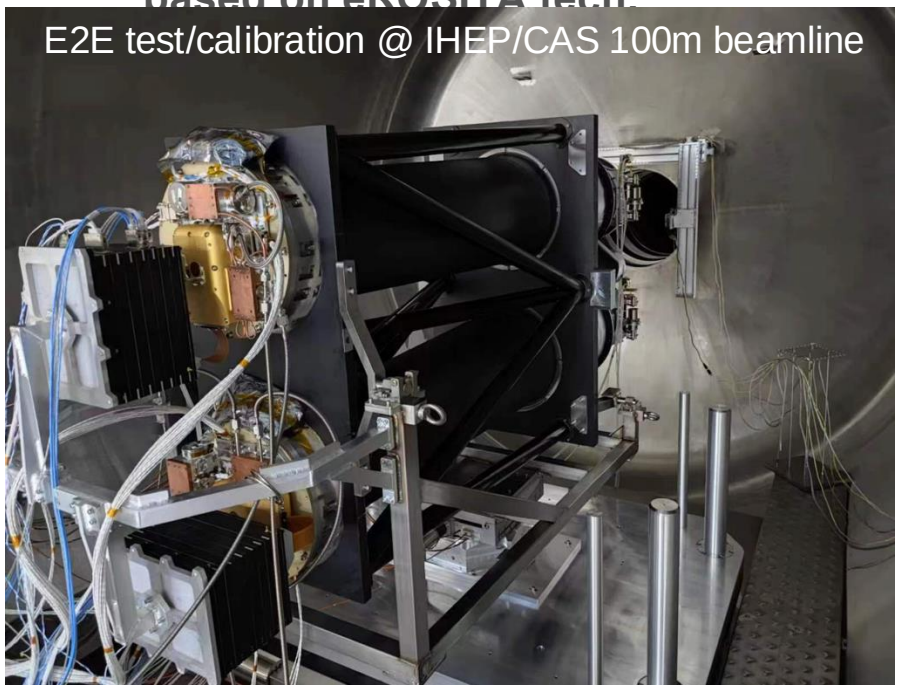
PSF scaning in 25 directions

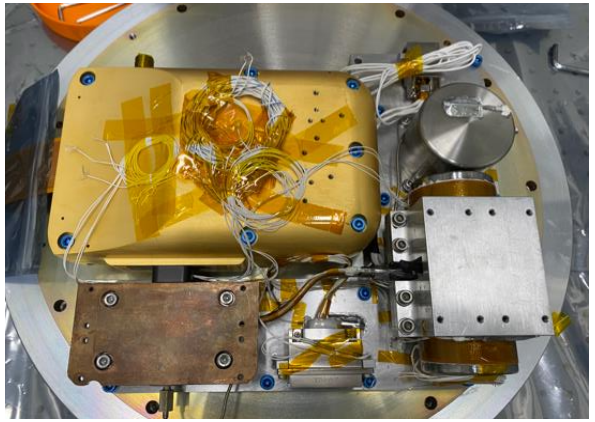


Follow-up X-ray Telescope (FXT)

IHEP/CAS + ESA + MPE

- 2 Wolter-I mirror assemblies
  - 1 by ESA (Media-Lario, eROSITA design)
  - 1 by MPE (eROSITA FS)
- X-ray cameras (IHEP)
  - PN-CCD detector modules by MPE based on eROSITA tech.

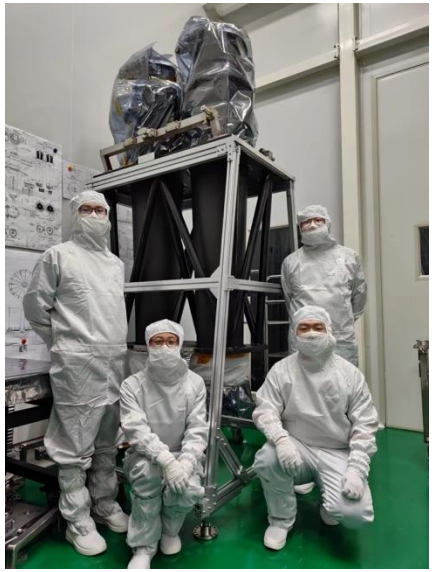




X-ray camera built @ IHEP/CAS

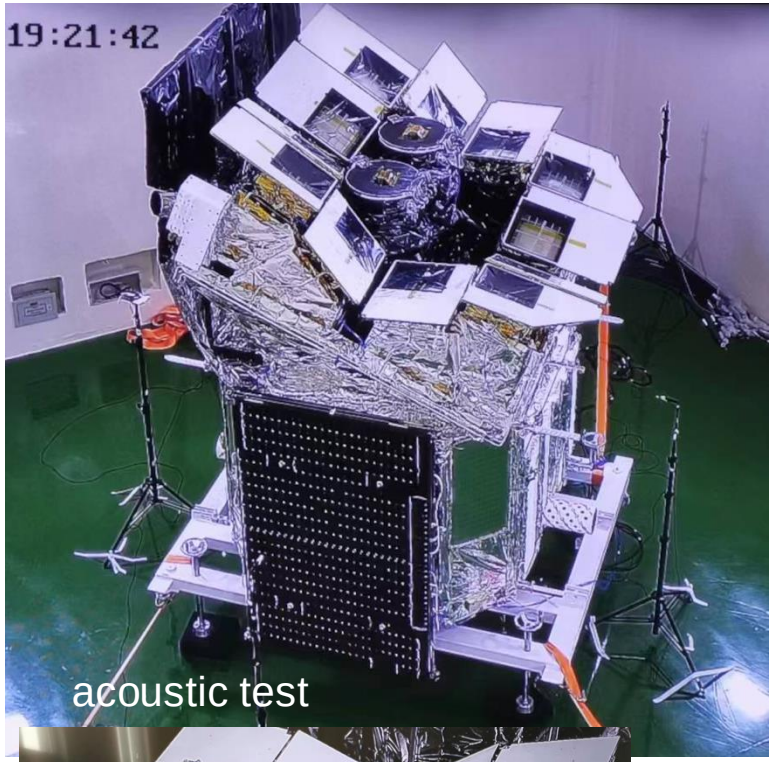
PI: Yong Chen (IHEP/CAS)

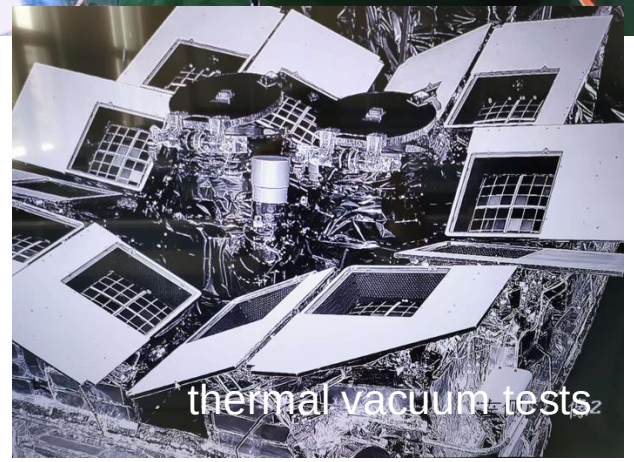
Camera lead: Weiwei Cui (IHEP/CAS)



FXT Delivered by IHEP team to MicroSAT on May 26

EP satellite



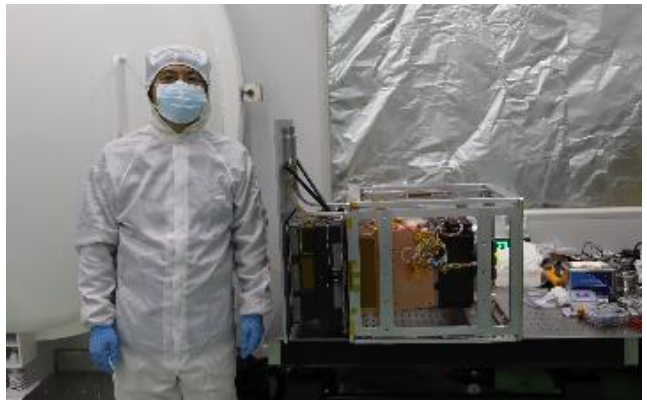


S/C developed @ MicroSat/CAS, Integration & tests

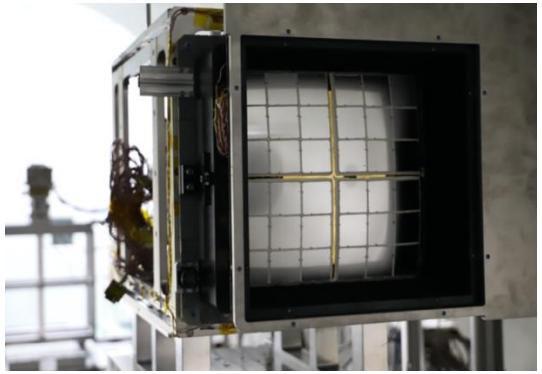
Satellite weight	1430 kg
Power	1150 W
Dimension	3.418(H) × 2.591(D) × 10.309(W) meters

Lobster-Eye Imager for Astronomy (LEIA)

pathfinder of Einstein Probe

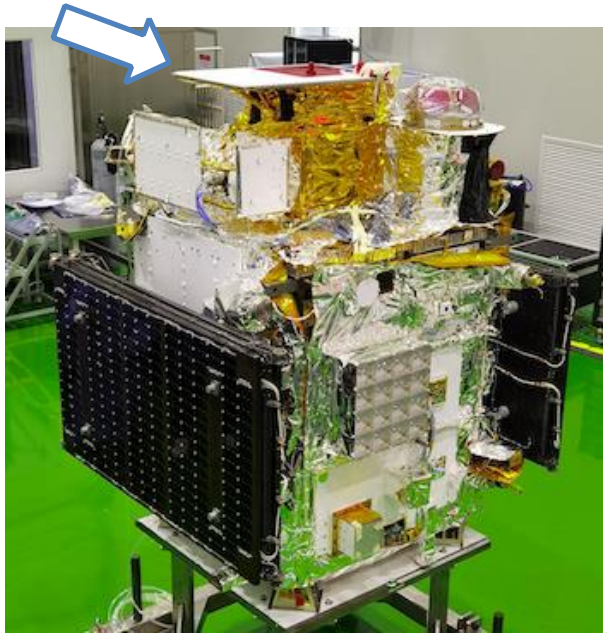


A WXT QM module, performance representative of WXT



LEIA 0.5 – 4 keV

Free piggyback, free launch



CAS's SATech-01 technology experiment satellite

credit: MicroSAT

launched 2022 July 27, @Jiuquan

launcher: CAS's Lijian-1 solid-fuel rocket

Sun-synchronous orbit ~ 95min

limited observing time:

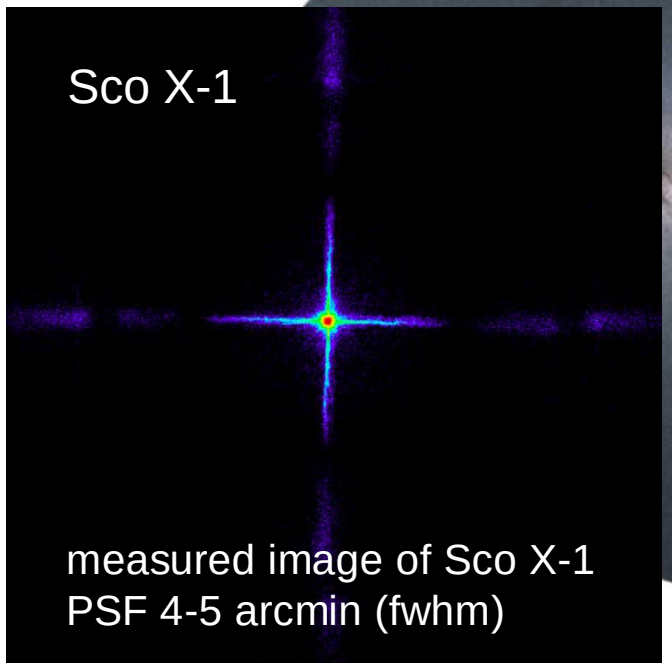
10 orbits/day, 10-15min/orbit

LEIA's first light: Galactic Centre region

Instrument test observations
August 8-10, 2022

FoV 340 deg^2

~800s exposure



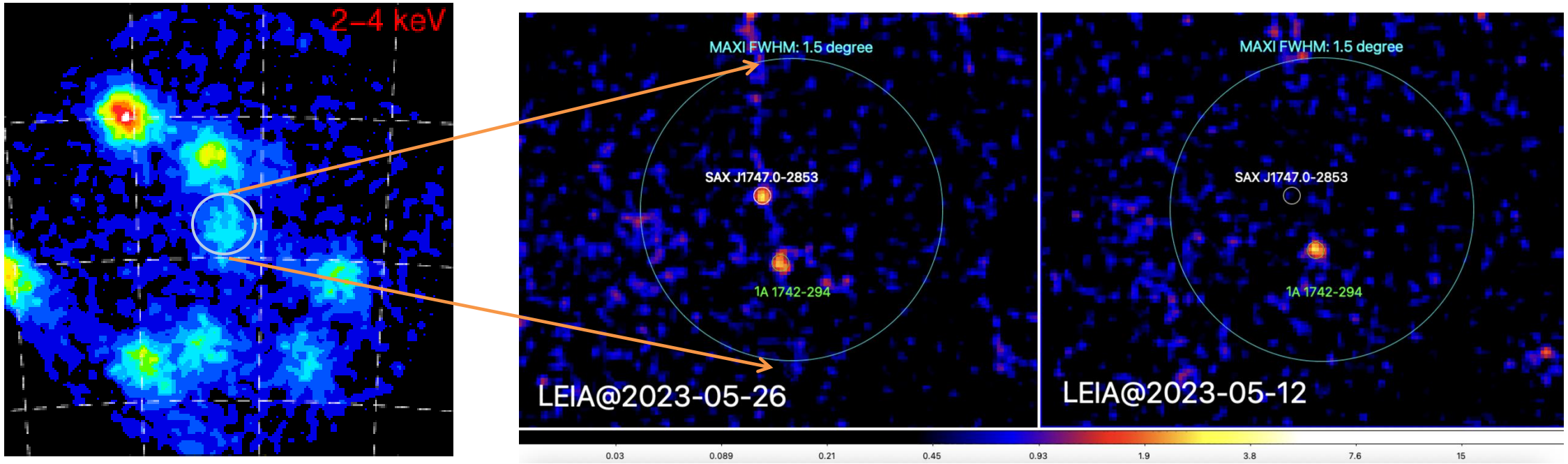
"*Frist wide-FoV X-ray observations by a lobster-eye focusing X-ray telescope in orbit*"
Zhang et al. 2022 ApJL, 941, L2

LEIA: improved resolution & sensitivity for ASM

The brightening of SAX J1747.0-2853 around Galactic centre

MAXI image (PSF~1.5°)

LEIA images (PSF~5')



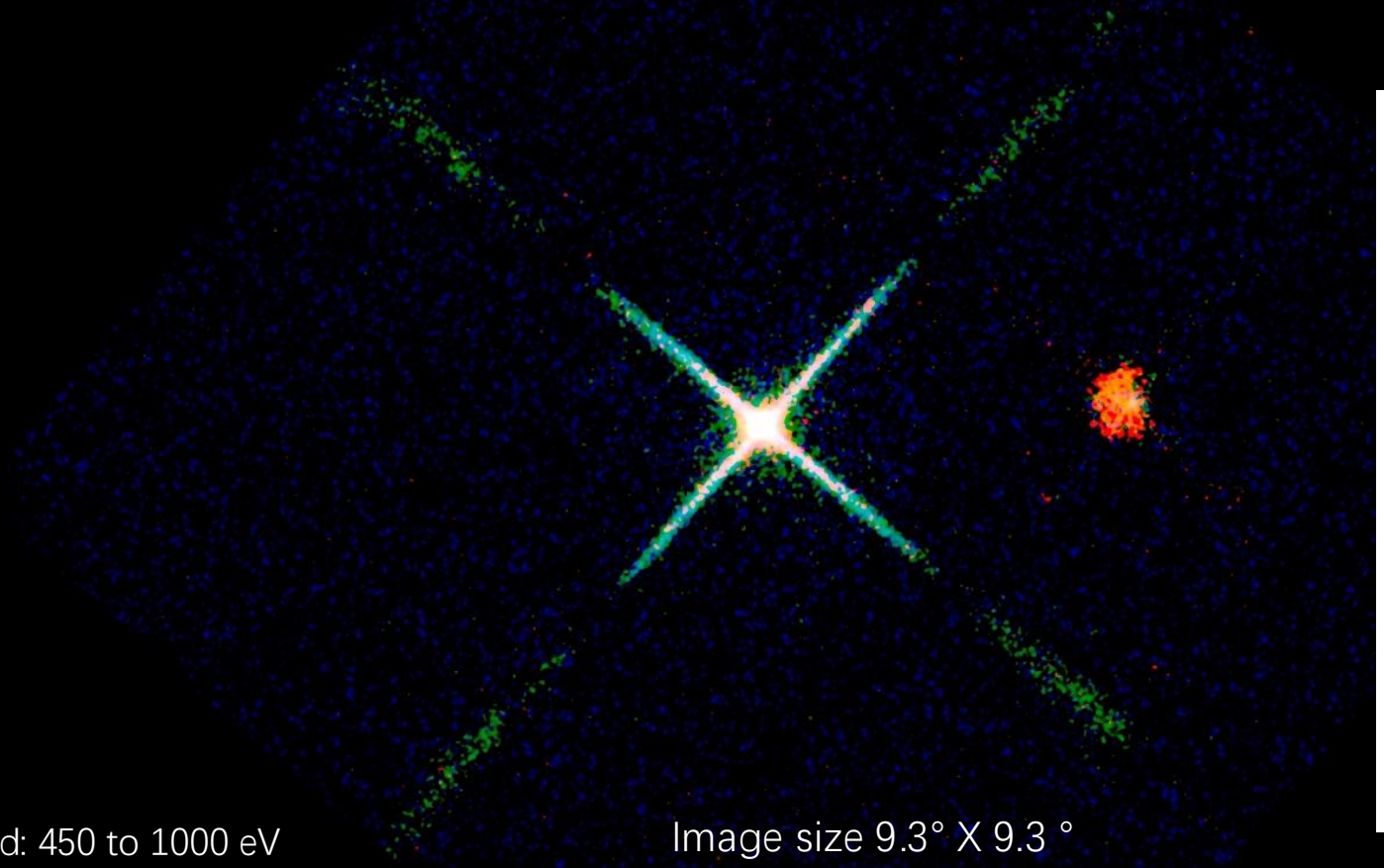
ATel #16061 Li D.Y, 2023 "*LEIA detected possible brightening of SAX J1747.0-2853* …"

Sensitivity (2-3) x10^{-11} erg/s/cm^2 (~1mCrab in 0.5-4keV) @1ks exposure

Source position uncertainties: ~ 2 arcmin (90% uncertainty)

X-ray First light 2024 Feb. 19

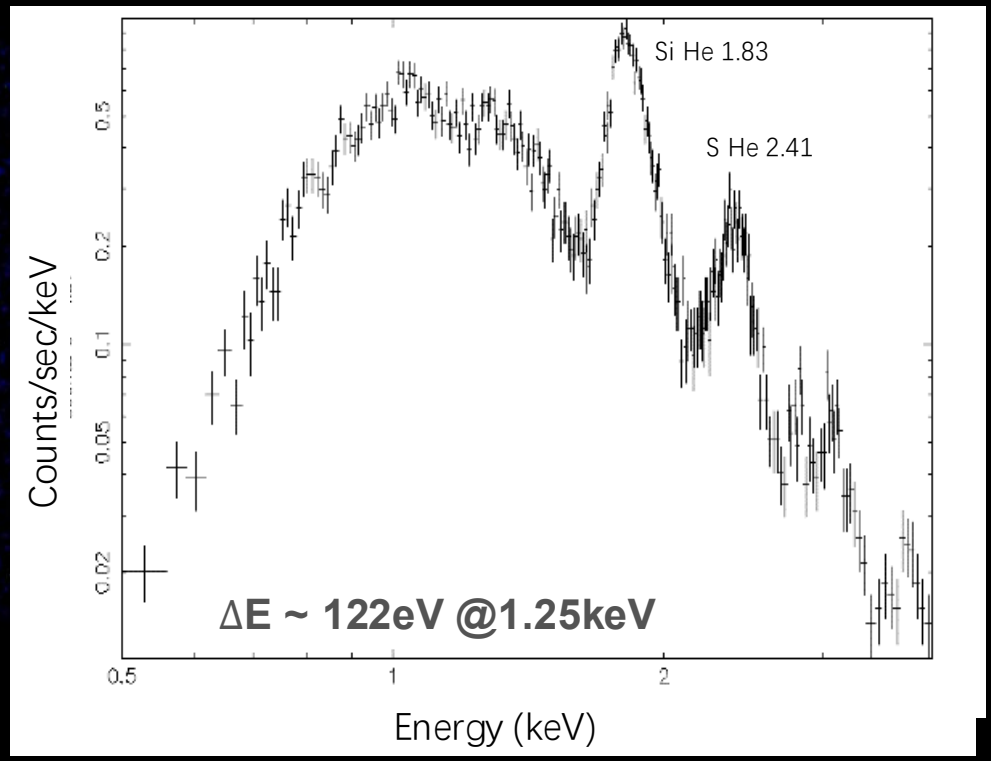
Cassiopeia A supernova remnant (nebula)



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

Image size 9.3° X 9.3 °
exposure 22 kilo-seconds

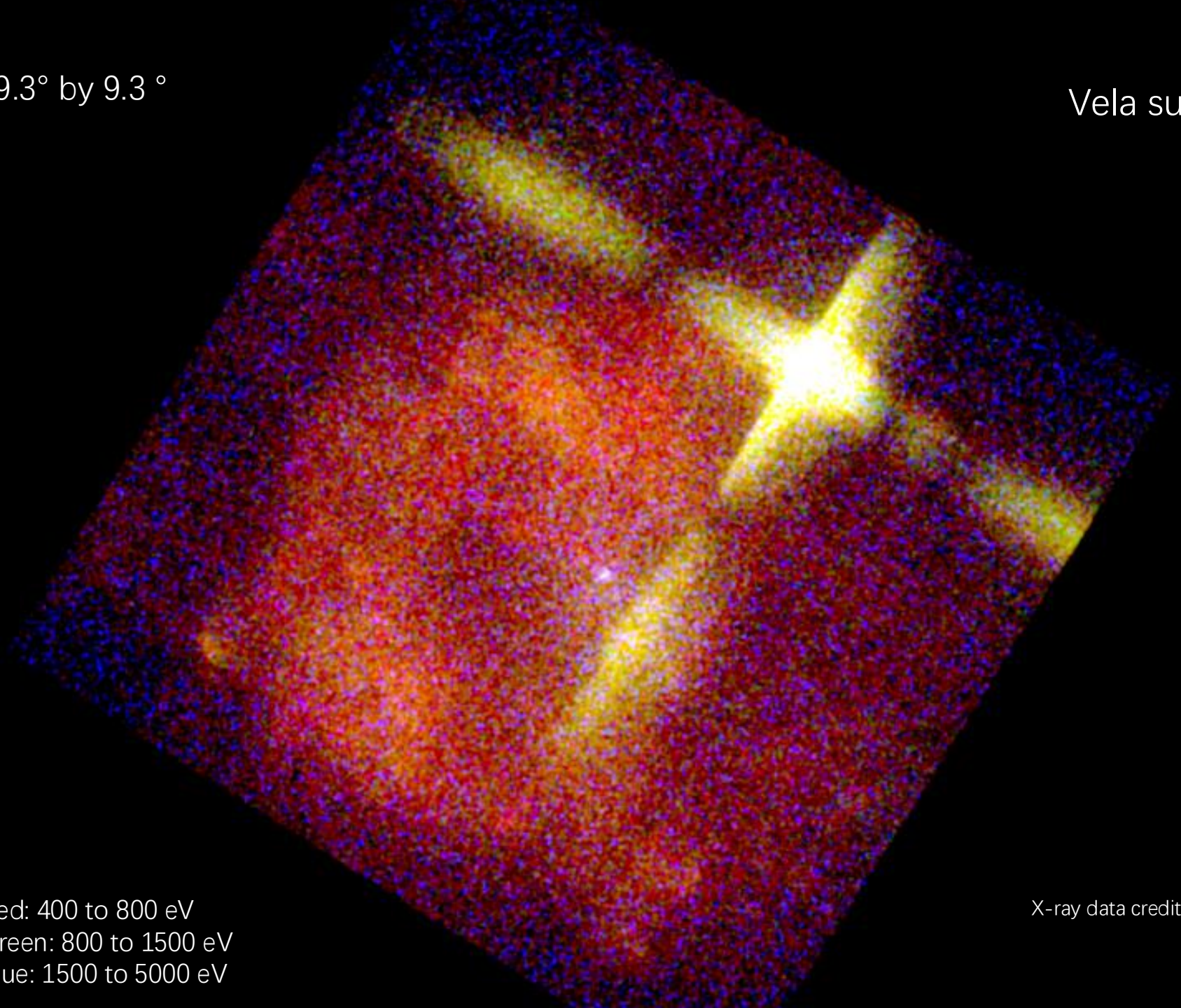
X-ray spectrum obtained at the same time



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

9.3° by 9.3 °

Vela supernova remnant X-ray (nebula)



exposure 9.3 kilo-seconds
mage size 9.3° X 9.3 °

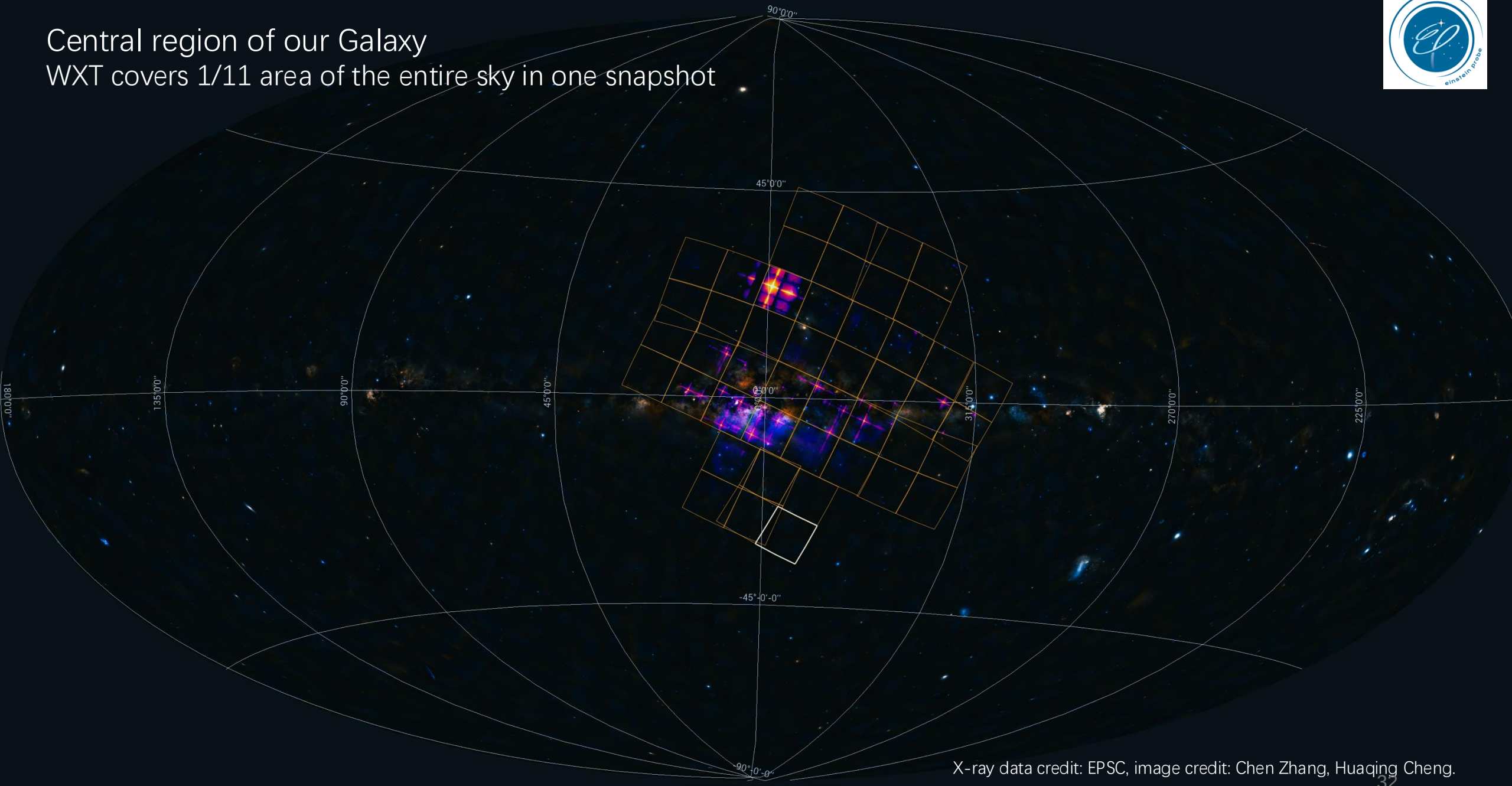
Vela supernova exploded about 11000 yr ago
936 light years to Earth

Red: 400 to 800 eV
Green: 800 to 1500 eV
Blue: 1500 to 5000 eV

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

Central region of our Galaxy

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

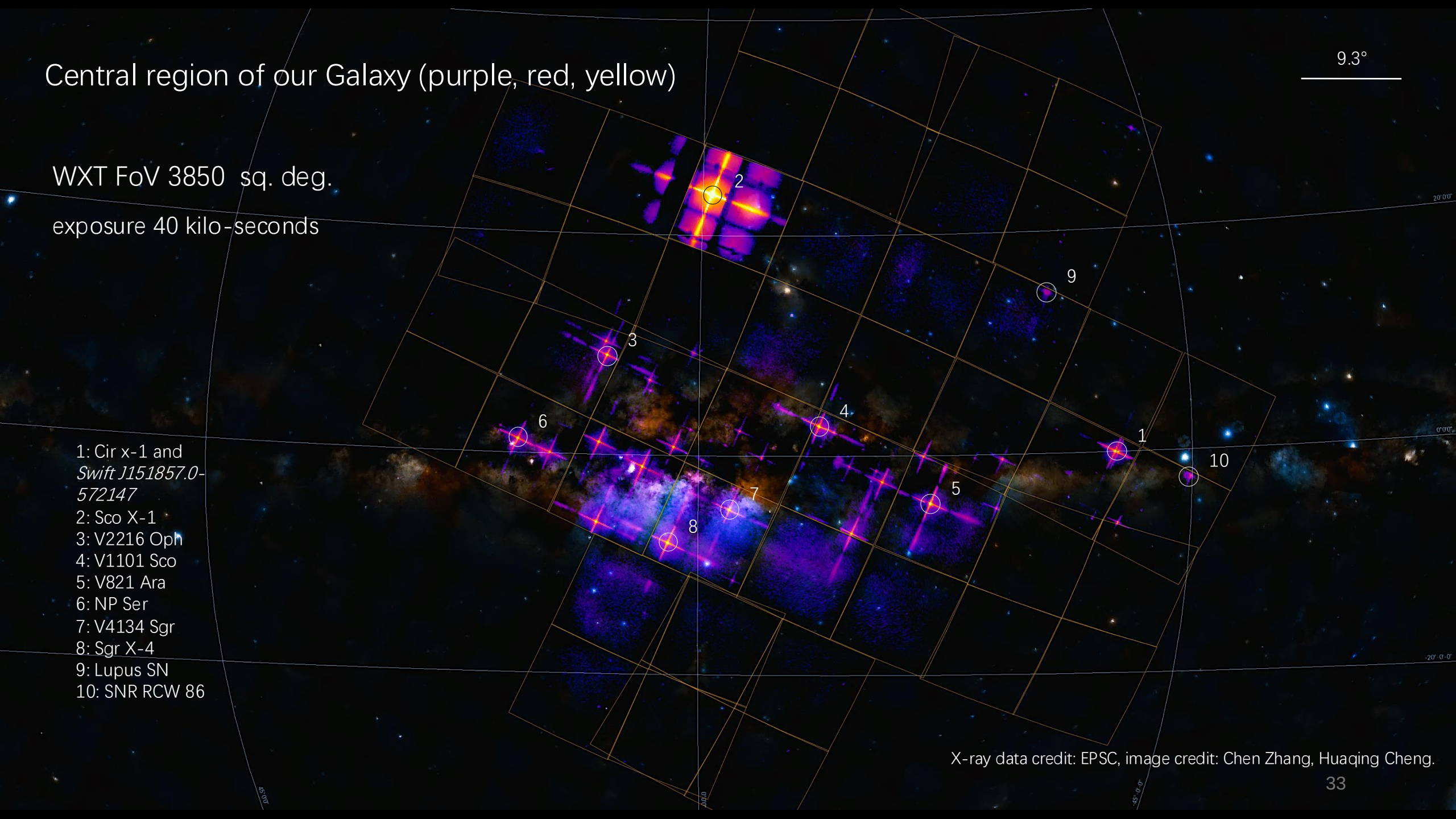


X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.

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

WXT FoV 3850 sq. deg.

exposure 40 kilo-seconds



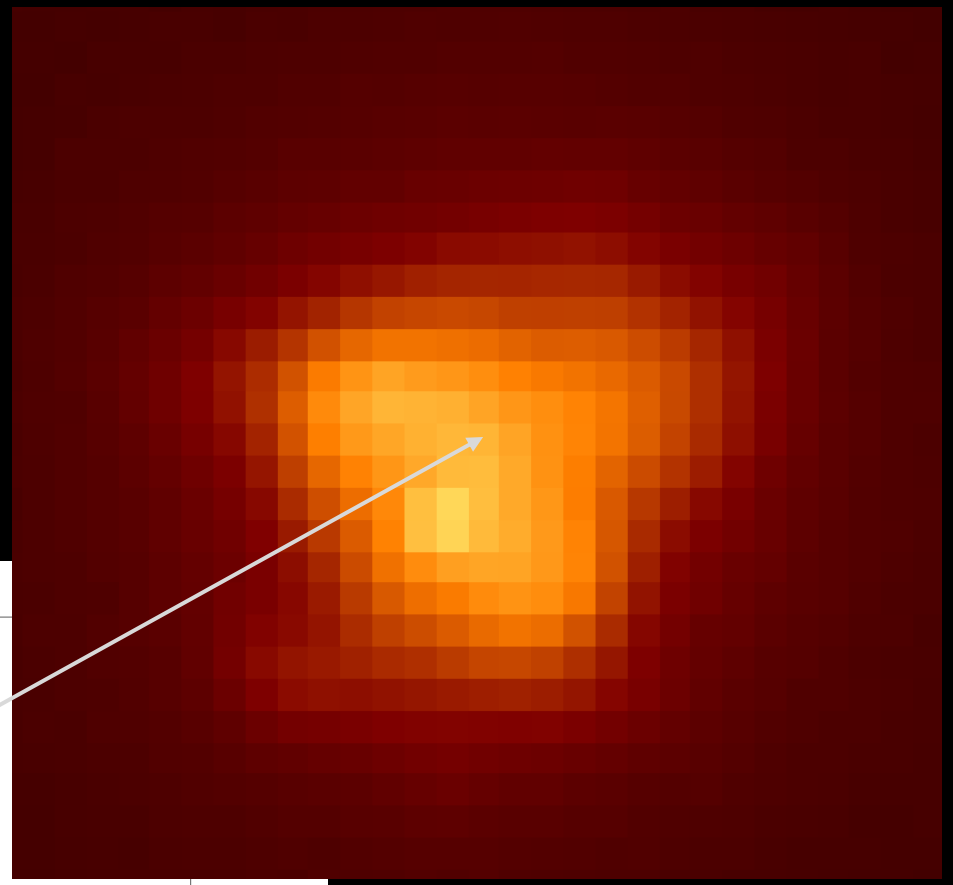
1: Cir x-1 and *Swift J151857.0-572147*
2: Sco X-1
3: V2216 Oph
4: V1101 Sco
5: V821 Ara
6: NP Ser
7: V4134 Sgr
8: Sgr X-4
9: Lupus SN
10: SNR RCW 86

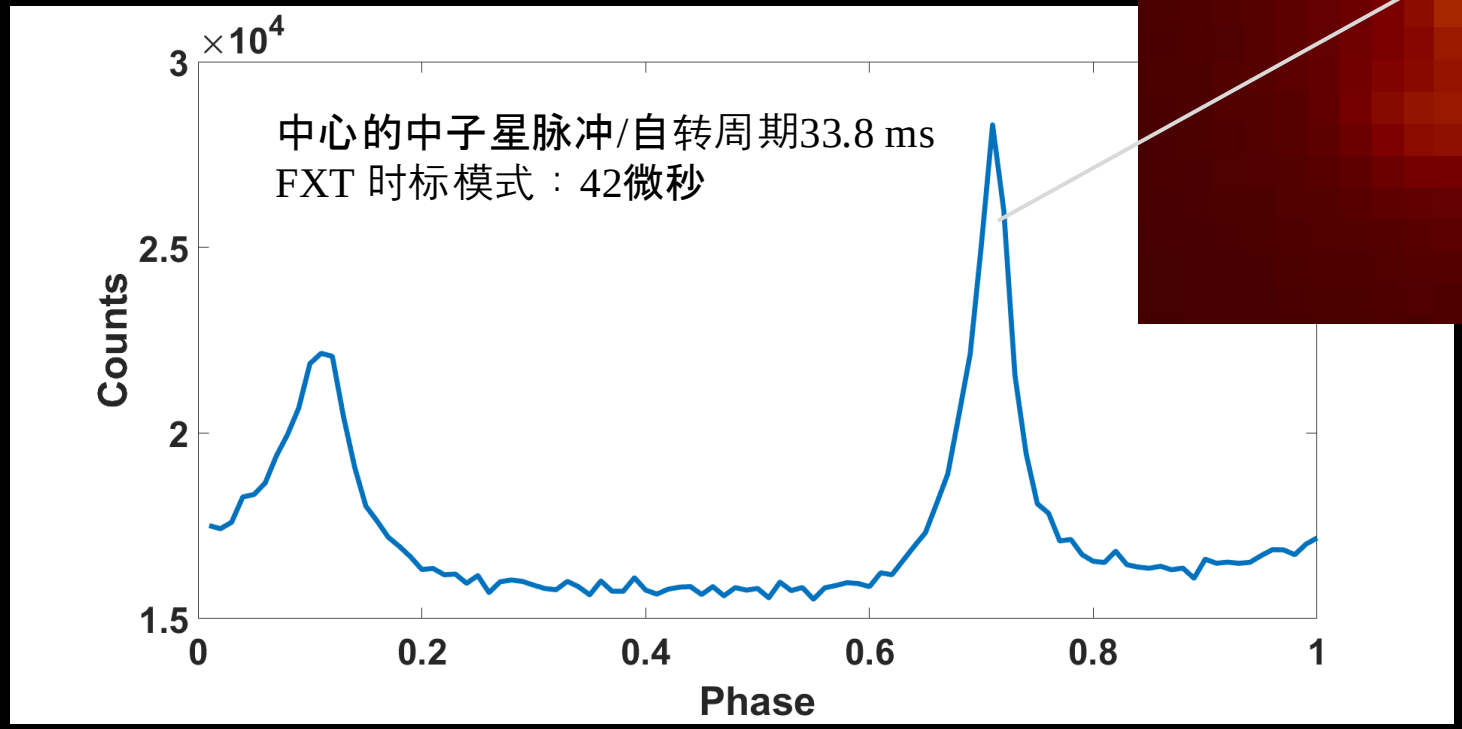
X-ray data credit: EPSC, image credit: Chen Zhang, Huaqing Cheng.

FXT X-ray First light

Crab nebula supernova remnant

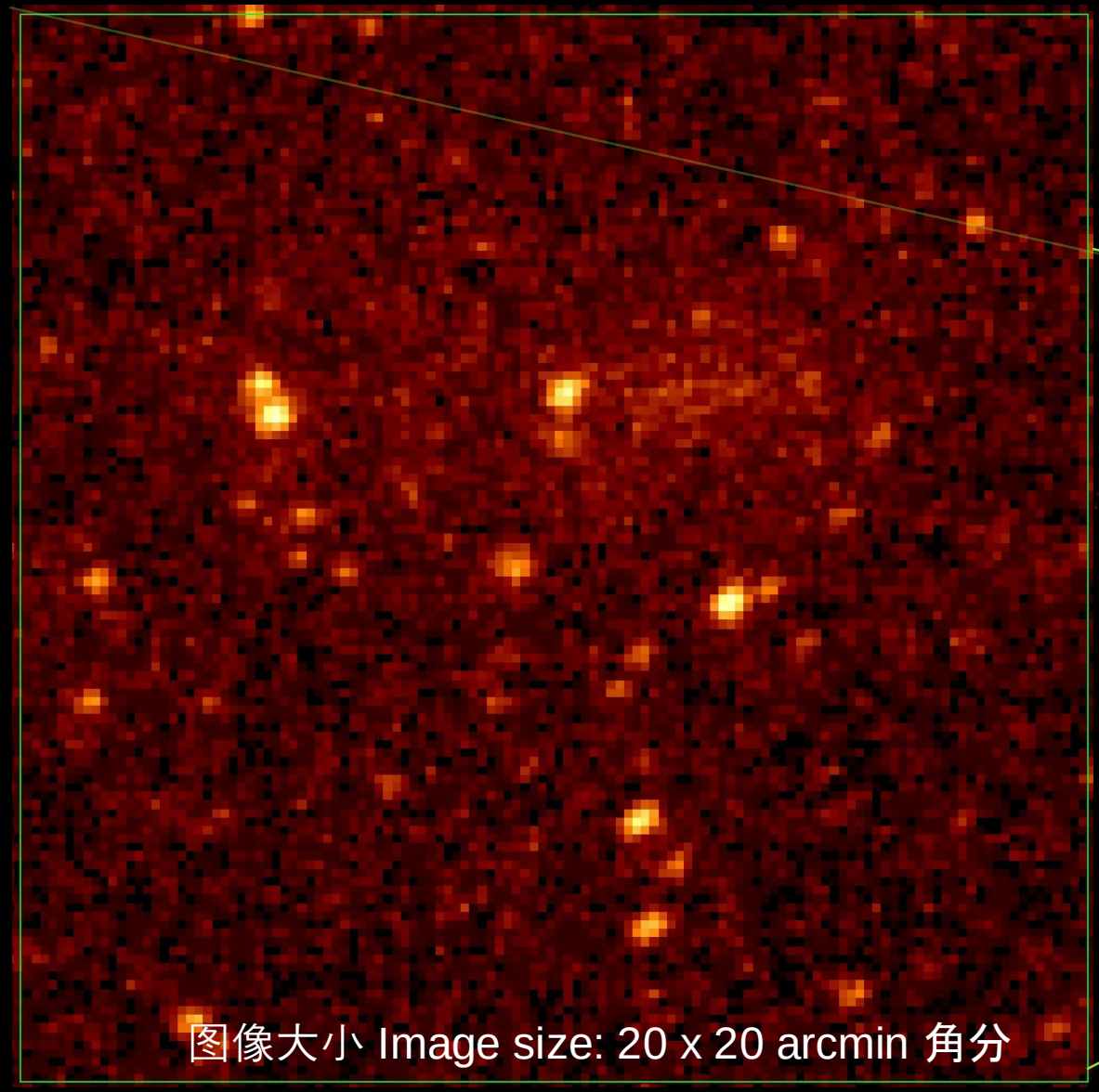
Band 0.3-10 keV
Exposure 2600s





半人马座 ω 球状星团 FXT. X-射线图像

Omega Centauri globular cluster X-ray image by FXT

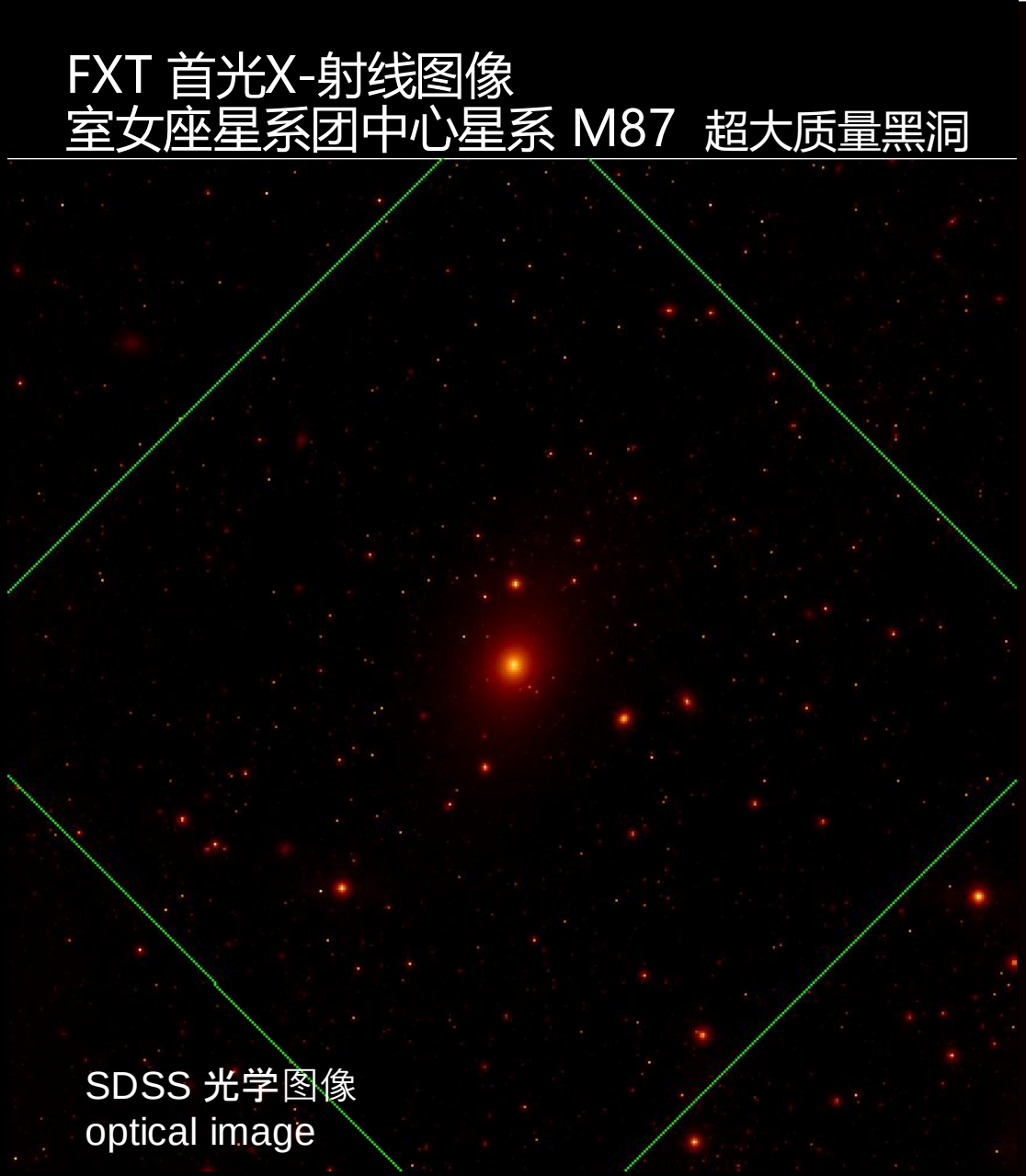


20 arcmin

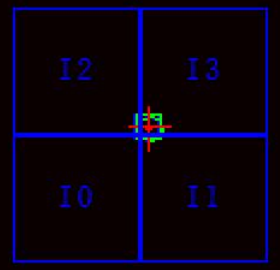
图像大小 Image size: 20 x 20 arcmin 角分

曝光时间 Exposure: 68 ks
0.3-10 keV
视场 FoV: 1°x1°

FXT 首光X-射线图像
室女座星系团中心星系 M87 超大质量黑洞

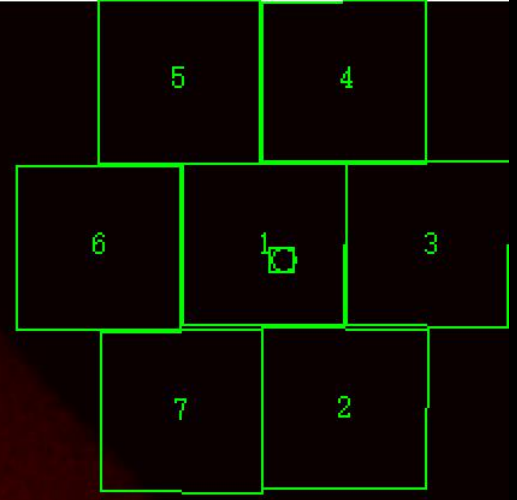


SDSS 光学图像
optical image



XIS

Suzaku
XIS FoV



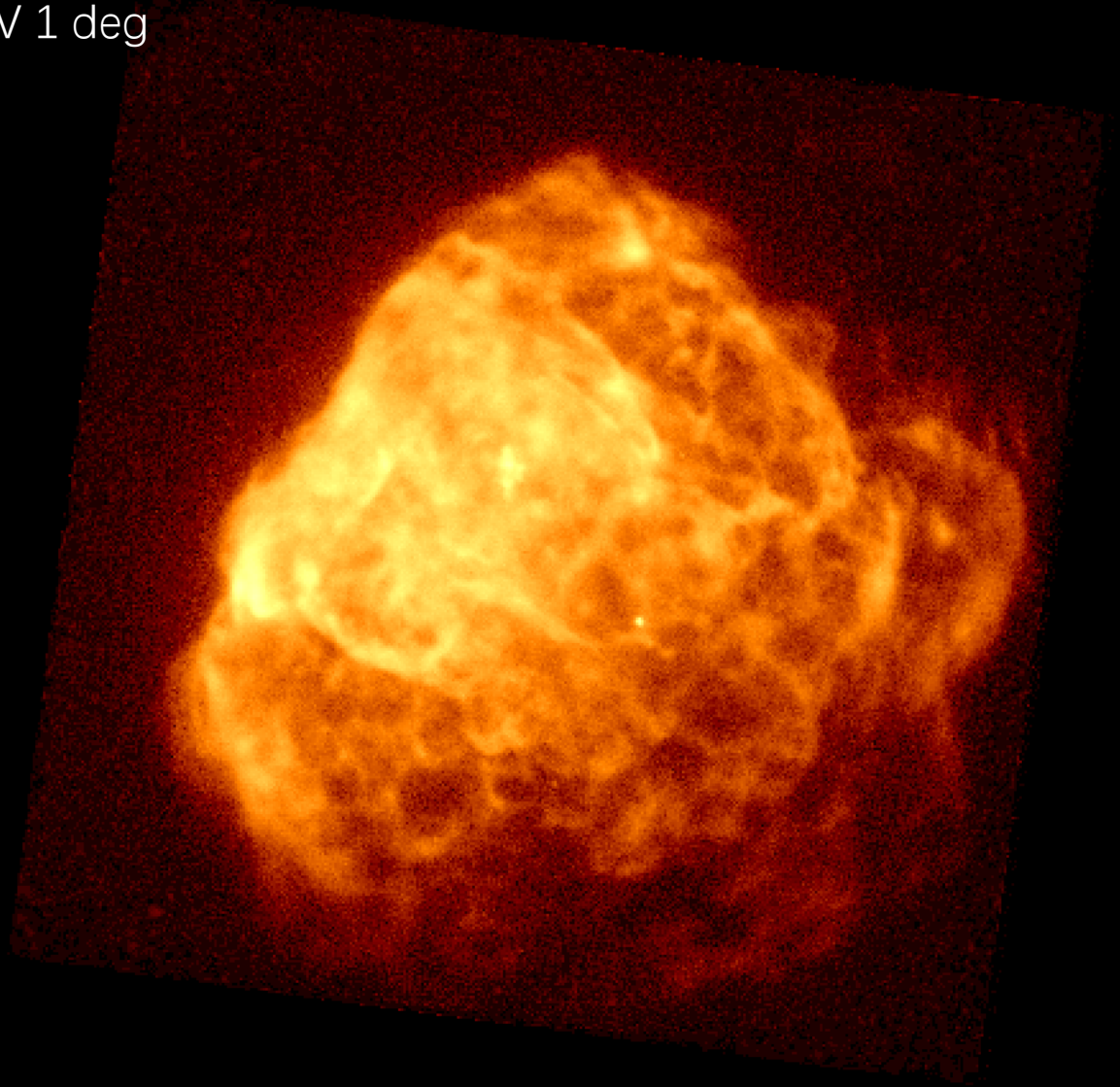
冷锋 cold front

0.3-10 keV
FoV 1°x1°
曝光时间 Exposure time: 39 ks

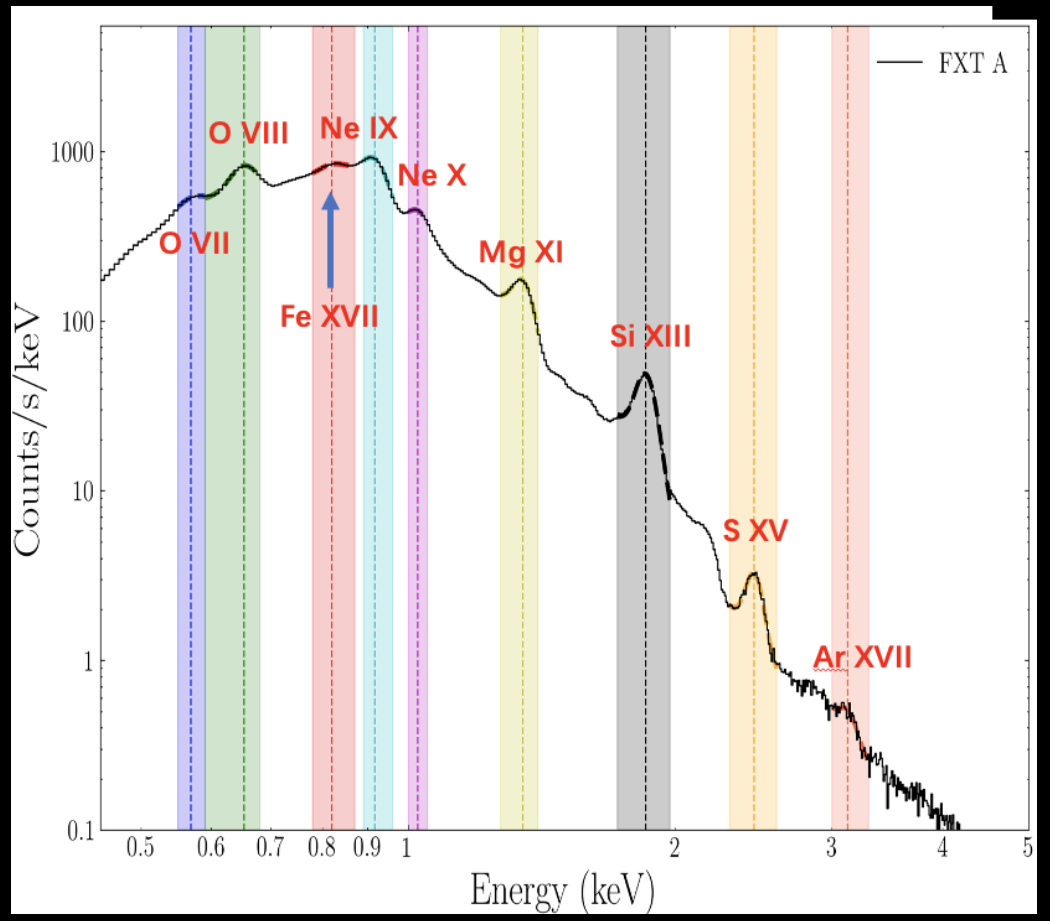
FXT X-ray First light (0.3-10 keV)

Puppis A supernova remnant (nebula)

FoV 1 deg

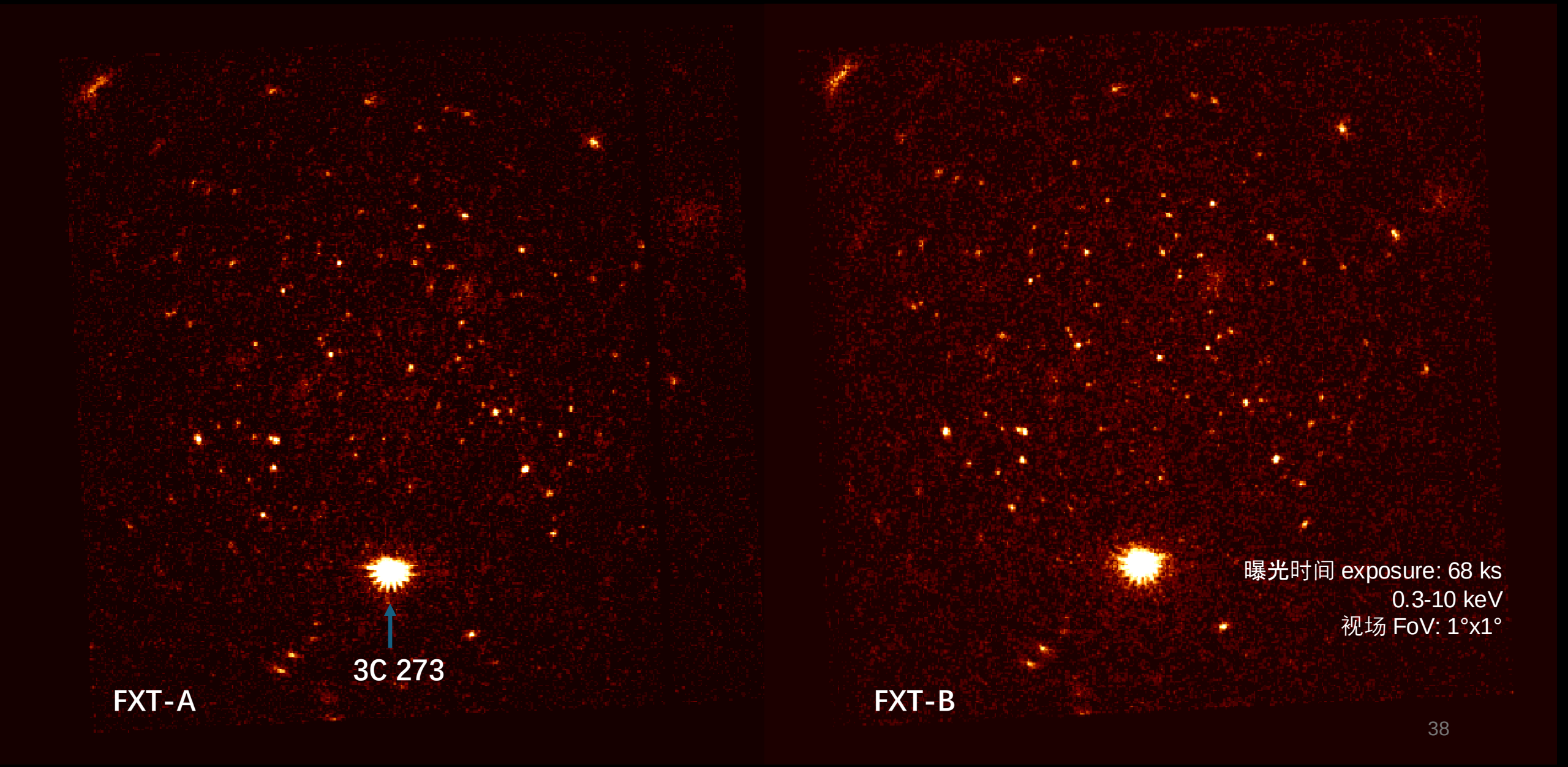


FXT X-ray spectrum obtained at the same time

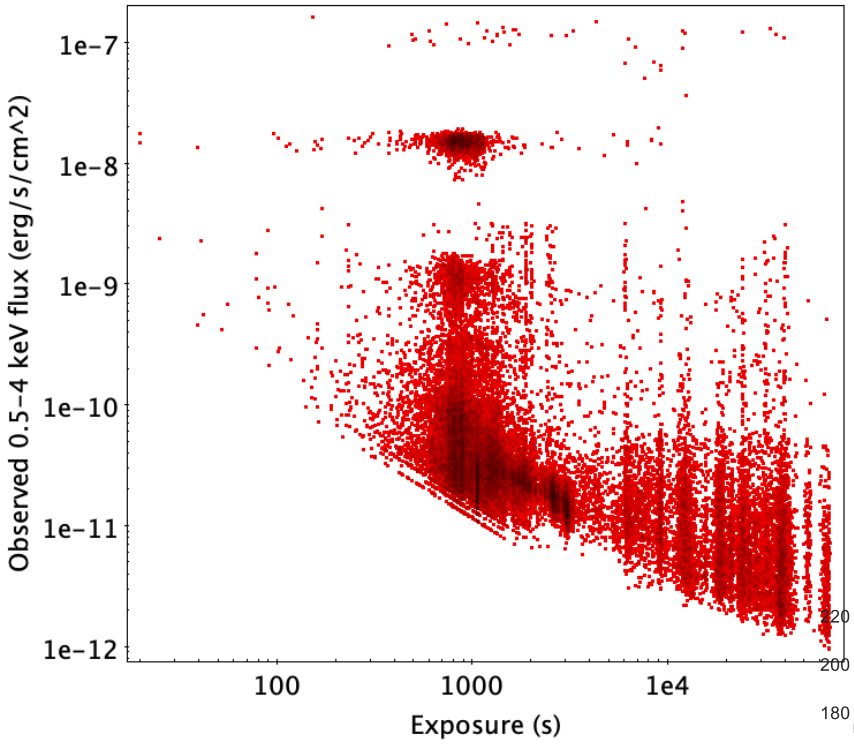


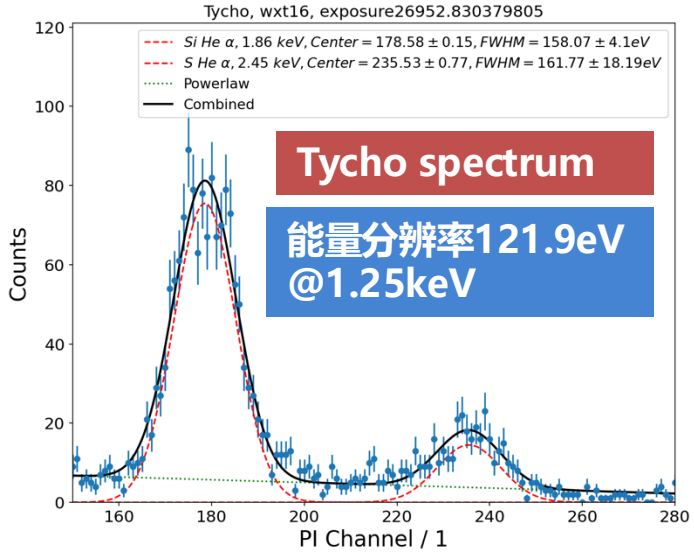
FXT 对类星体 3C273 附近天区的X 射线观测图像

~100 新 X 射线源探测



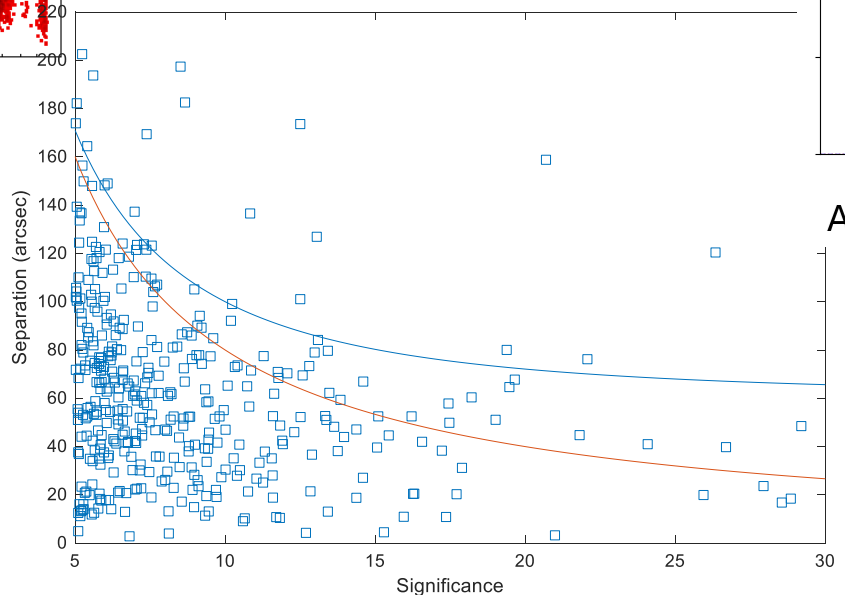
The most sensitive X-ray all-sky monitor

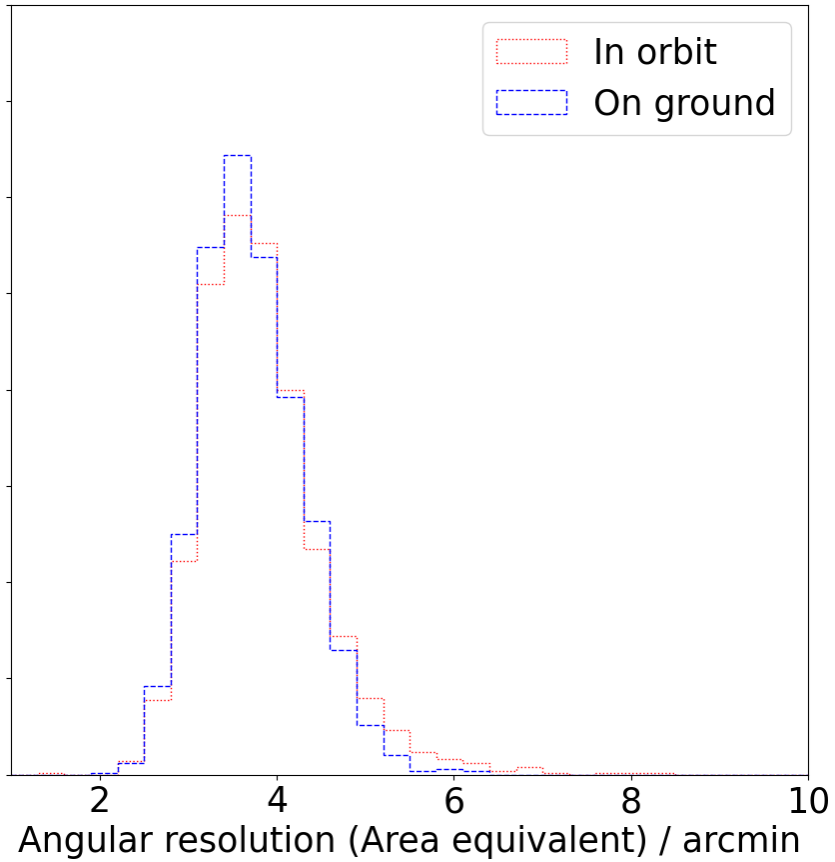




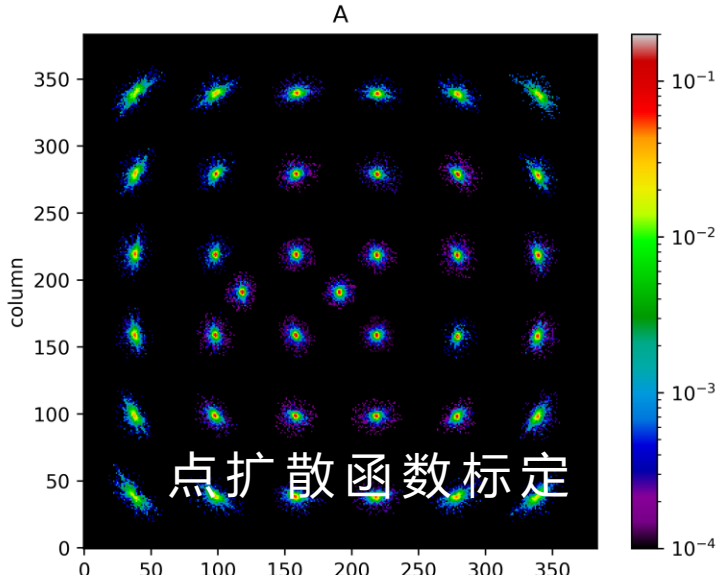
Tycho spectrum

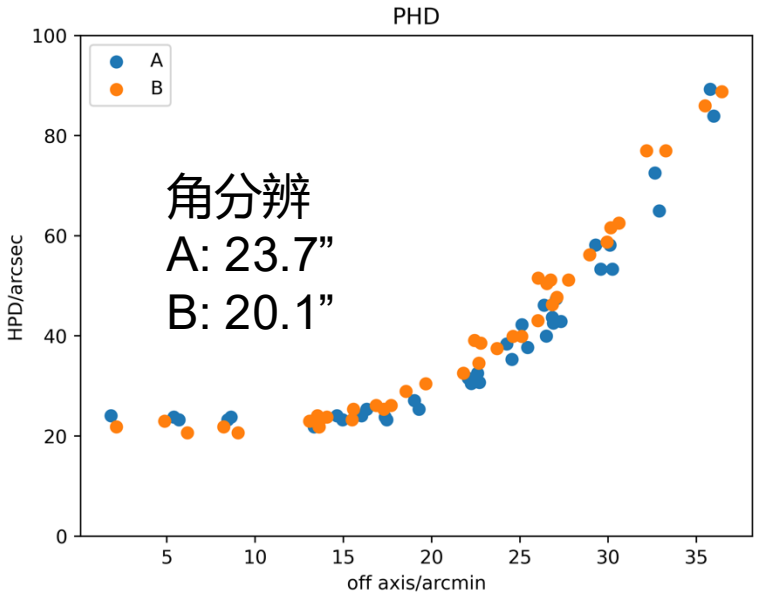
能量分辨率121.9eV @1.25keV

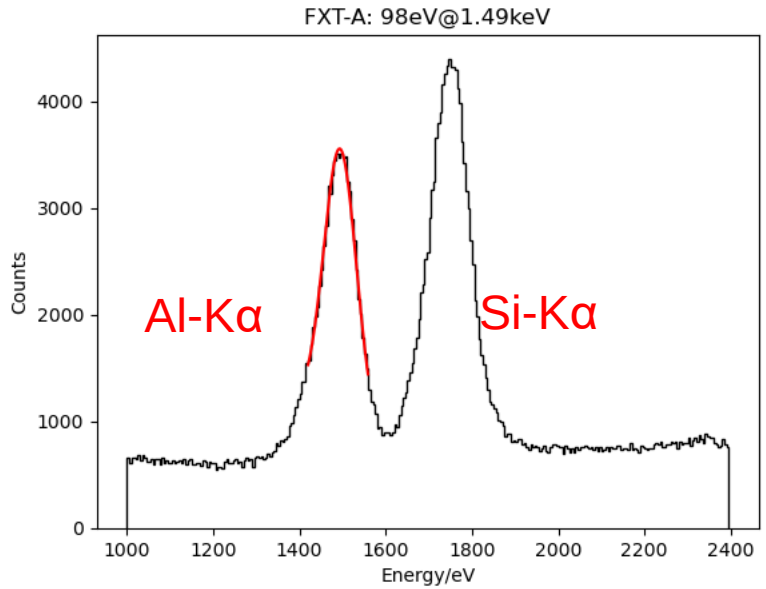


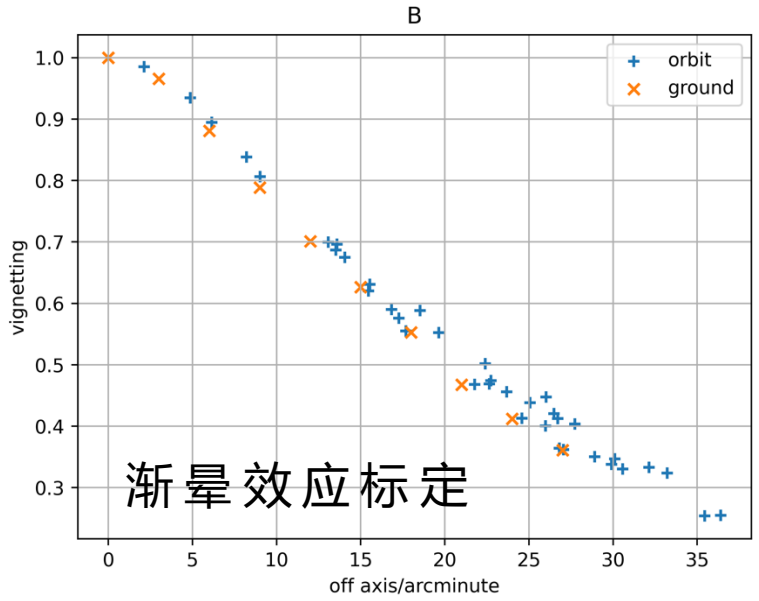


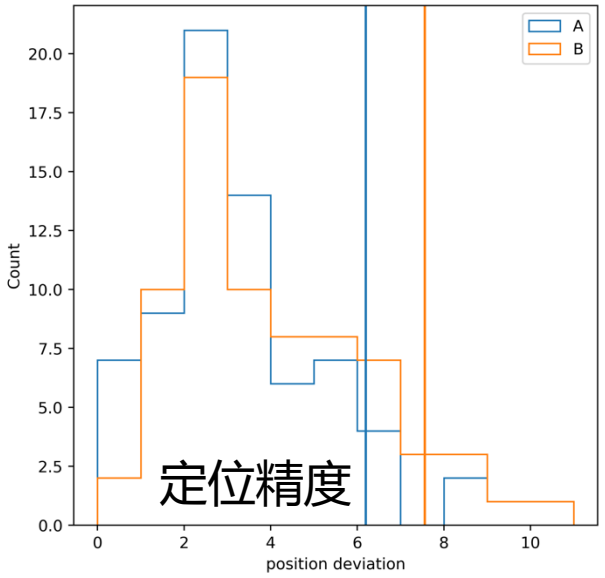
FXT （风行天）在轨测试结果与地面标定测试基本一致

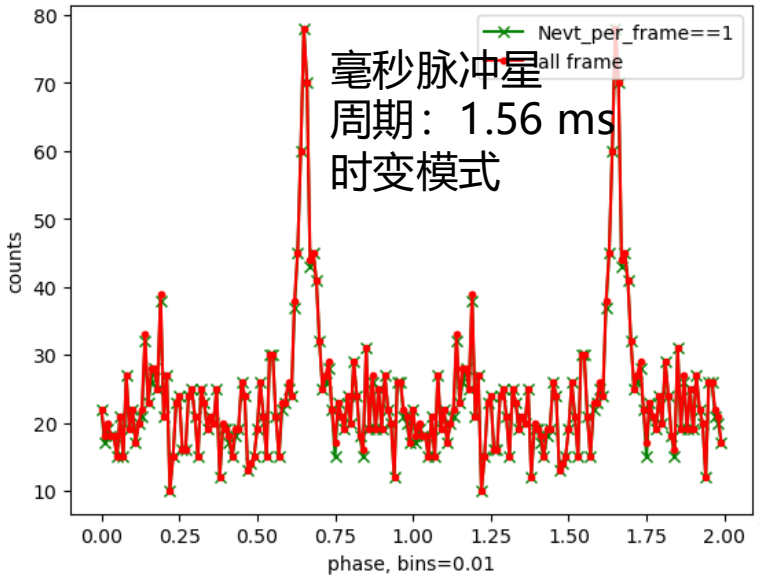












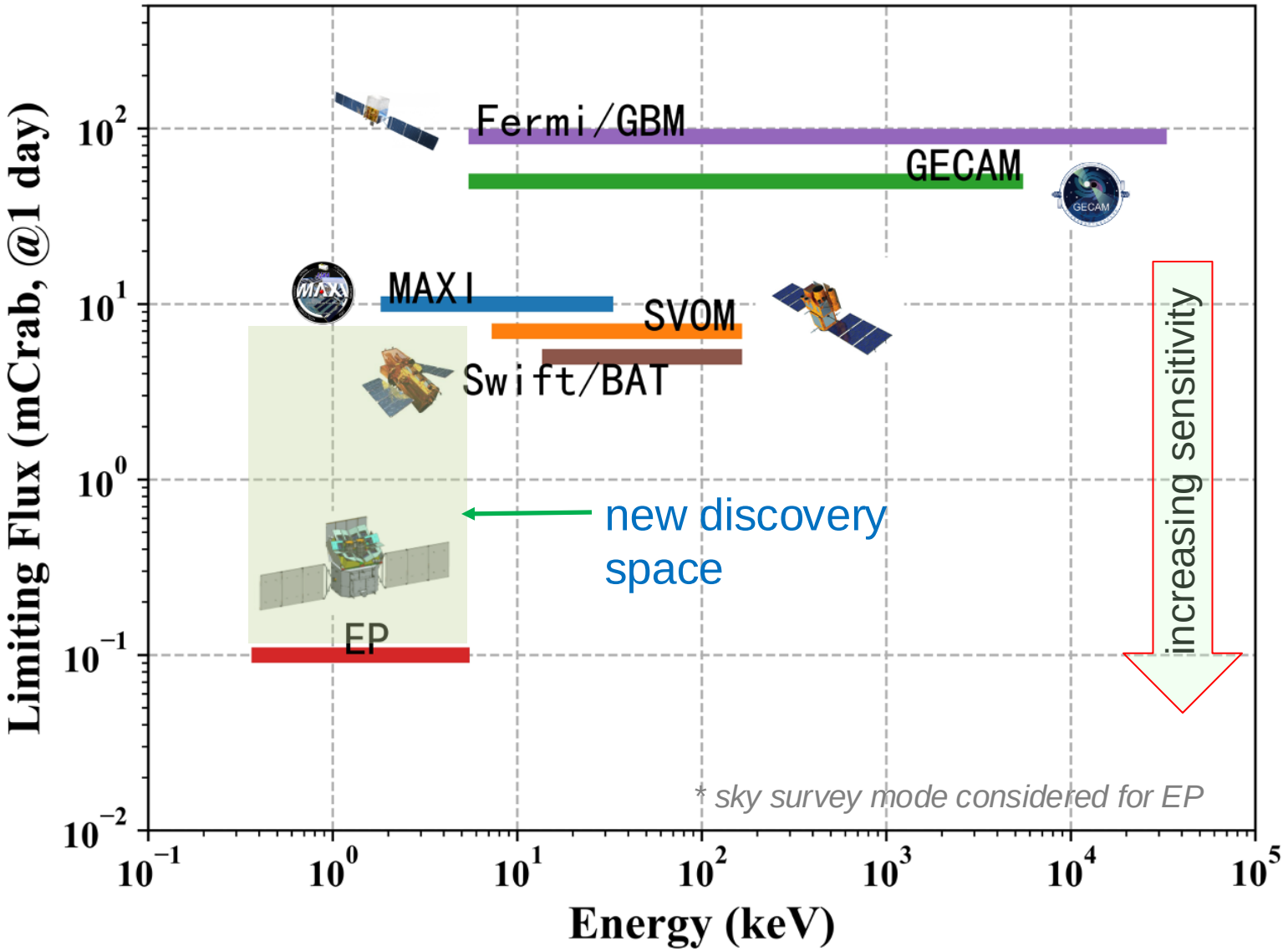
供图：陈勇、赵晓帆、李承奎、韩大炜

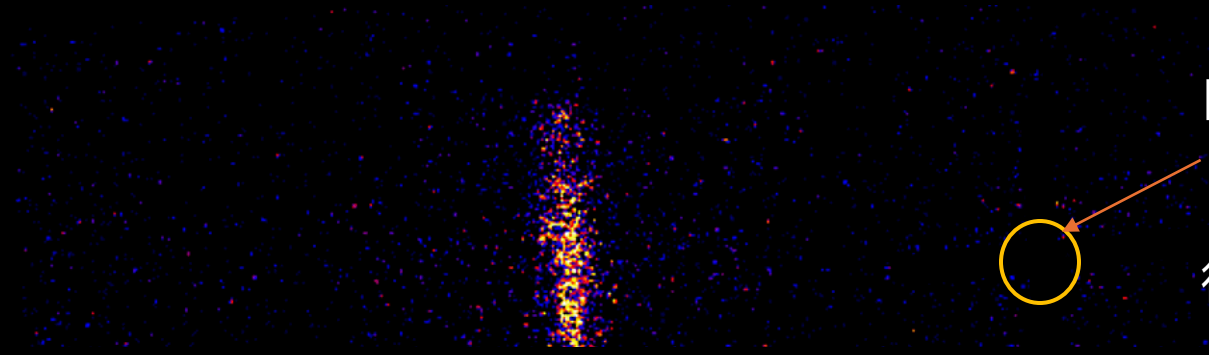
Performance

No.	Item	Specifications	Performance
1	Pointing accuracy Instrument coordinate	≤ 1 arcmin (90% Confidence interval)	0.7 arcmin
2	Pointing accuracy J2000	≤ 2 arcmin (90% Confidence interval)	<2 arcmin
3	Total FOV	≥3600 sq. deg.	3850 sq. deg.（calculated result）
4	Band range	0.5 keV~4 keV	0.4 keV~6 keV
5	Effective area	≥2 cm2 @ 1 keV	~3 cm2 @ 1 keV
6	Angular resolution	≤ 5 arcmin@ 1 keV	3.3~4.4 arcmin（R60）
7	Energy resolution	≤170 eV @ 1.25 keV	120~140 eV @ 1.25 keV

Comparison of sensitivity and energy band

- Higher sensitivity by 1-2 orders of mag. than those in orbits
- Large FoV (~ 1 str)
- Soft X-ray (0.5-5 keV)





EP240219a： WXT探测并发布的第一例X 射线暂现源，

（在天文学家电报上）对全球发布

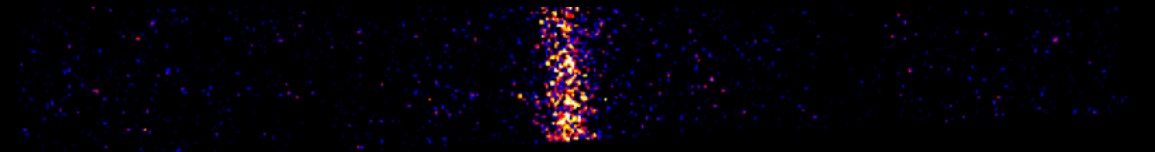
很可能是一例富含 X 射线的伽玛暴

Detection of a bright X-ray flare by Einstein Probe in its commissioning phase

Posted by Chen Zhang (NAOC, CAS), Z. X. Ling (NAOC, CAS), Y. Liu (NAOC, CAS), X. Pan (NAOC, CAS), C. C. Jin (NAOC, CAS), H. Q. Cheng (NAOC, CAS), C. Z. Cui (NAOC, CAS), D. W. Fan (NAOC, CAS), H. B. Hu (NAOC, CAS), J. W. Hu (NAOC, CAS), M. H. Huang (NAOC, CAS), D. Y. Li (NAOC, CAS), H. Y. Liu (NAOC, CAS), H. W. Pan (NAOC, CAS), H. Sun (NAOC, CAS), W. X. Wang (NAOC, CAS), Y. F. Xu (NAOC, CAS), M. Zhang (NAOC, CAS), W. D. Zhang (NAOC, CAS), W. J. Zhang (NAOC, CAS), Z. Zhang (NAOC, CAS), D. H. Zhao (NAOC, CAS), E. Kuulkers (ESA), P. O'Brien (Univ. of Leicester) and W. Yuan (NAOC, CAS), on behalf of the Einstein Probe team
*on **21 Feb 2024; 02:24 UT***

Subjects: X-ray, Transient

We report on the detection of a bright X-ray flare EPW20240219aa at 2024-02-19T06:23:27 (UTC) by one of the Wide-field X-ray Telescope (WXT) modules on board the Einstein Probe (EP) mission. The position of the source is R.A. = 80.016 deg, DEC = 25.541 deg (J2000) with an uncertainty of 3 arcmin (radius, 90% C.L. statistical and systematic). The source exhibits a fast rise to a peak 0.5 - 4.0 keV flux of approximately 5 x 10^-9 erg/s/cm^2 in about 10 seconds, followed by a relatively slow decay to the background level of 4 x 10^-11 erg/s/cm^2 within about 200 seconds. The averaged spectrum can be fitted by an absorbed power-law with NH = 8.6(-0.4/+0.5) x 10^21 cm^-2 and a photon index of 2.0(-0.8/+0.9). The derived average unabsorbed 0.5 - 4.0 keV flux is 6.9(-2.1/+5.6) x 10^-10 erg/s/cm^2. However, it should be noted the derived parameters of the source may be subject to larger uncertainties than those quoted here since in-orbit calibration of the instrument is still in progress.



9.3° by 9.3 °, 1 slice represent 33.3 sec

Yin et al. submitted

Start Time 20359 6:13:28:534 Stop Time 20359 6:30:43:534

地-星遥控 - FXT快速机遇目标（ToO）观测

- WXT 探测到暂现源 EP240414a (Lian et al. GCN 36091)
- 暂现源信息通过北斗/VHF 快速下传
- 北斗上注指令 FXT 快速机遇目标观测
- T0+ 2 小时: FXT开始观测，探测到 X 射线源
  - 距离 WXT 源1.5角分
- 发布暂现源警报，引导国际多个望远镜后随观测

  LOT + 3.13 hr (AT2024gsa, r= 21.52 mag)

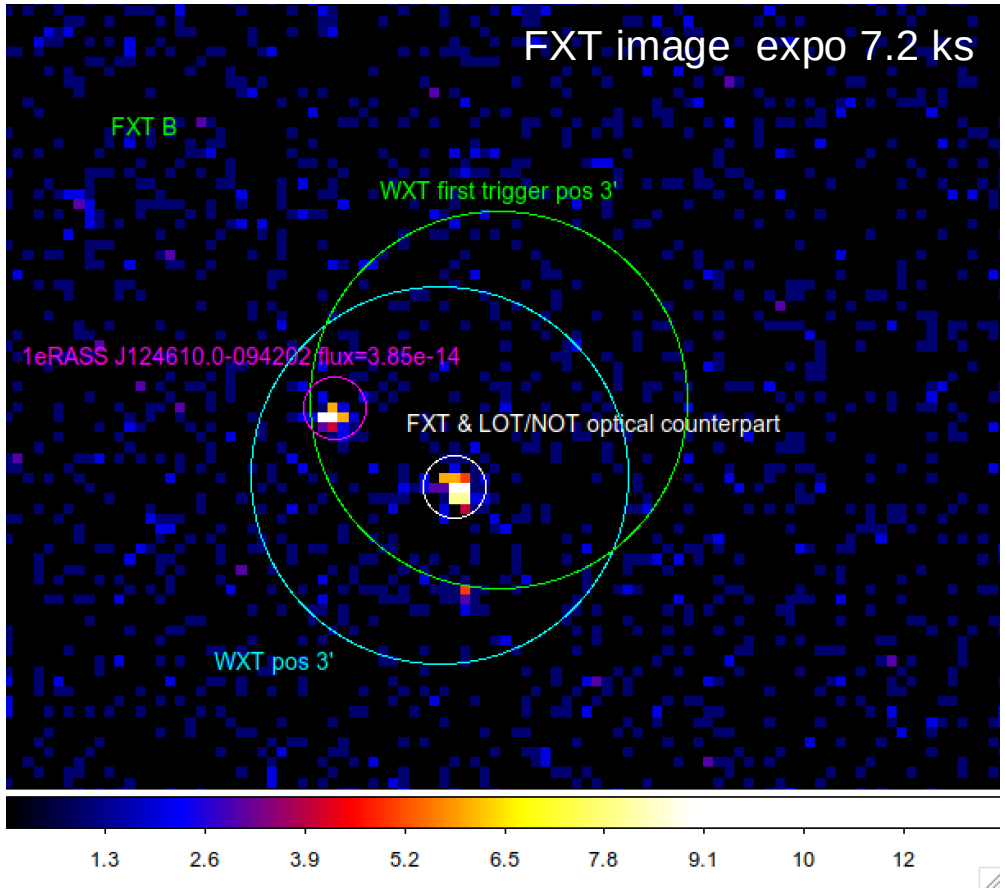
  NOT +2.29 hr

  GTC +5 hr

  BOOTES-4/MET +5.56 hr

  Pan-STARRS1 +2/3 d

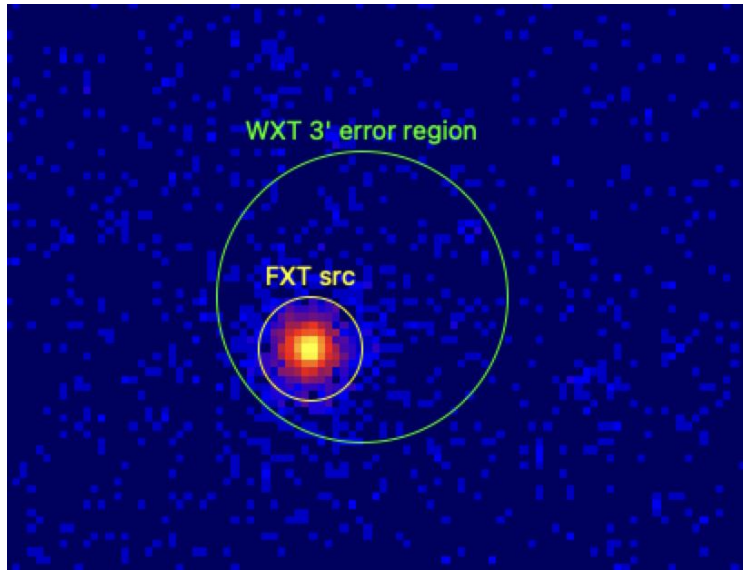
  GSP + 3.66 d
- 探测到成协的超新星爆发 (Levan et al. GCN 36355)
- 光学测量到寄主星系红移 = 0.41



90% 定位误差
WXT: 2.1 arcmin
FXT: < 10 arcsec

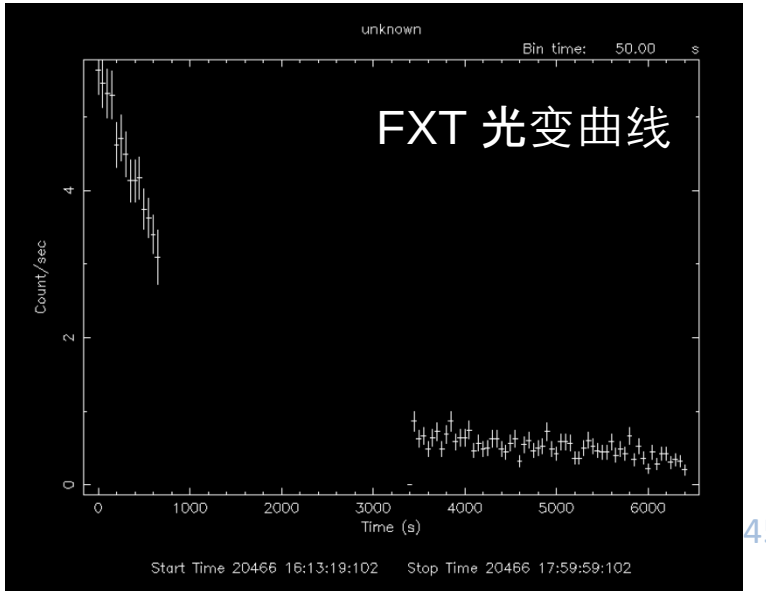
星上探测、触发和FXT 自动后随观测

- 6 月 5 日 UTC 16:10:30　WXT 探测到暂现源 EP240605a
- 暂现源信息通过北斗/VHF 快速下传
- 星上自动触发 FXT 自主后随观测 UTC 16:11:44
  - 触发1分钟后 开始观测
  - Exp. Time 3.6 ks　&　Flux: 1.3e-11 erg/cm2/s
  - FXT X 射线光谱 表明是 恒星 X 射线耀发

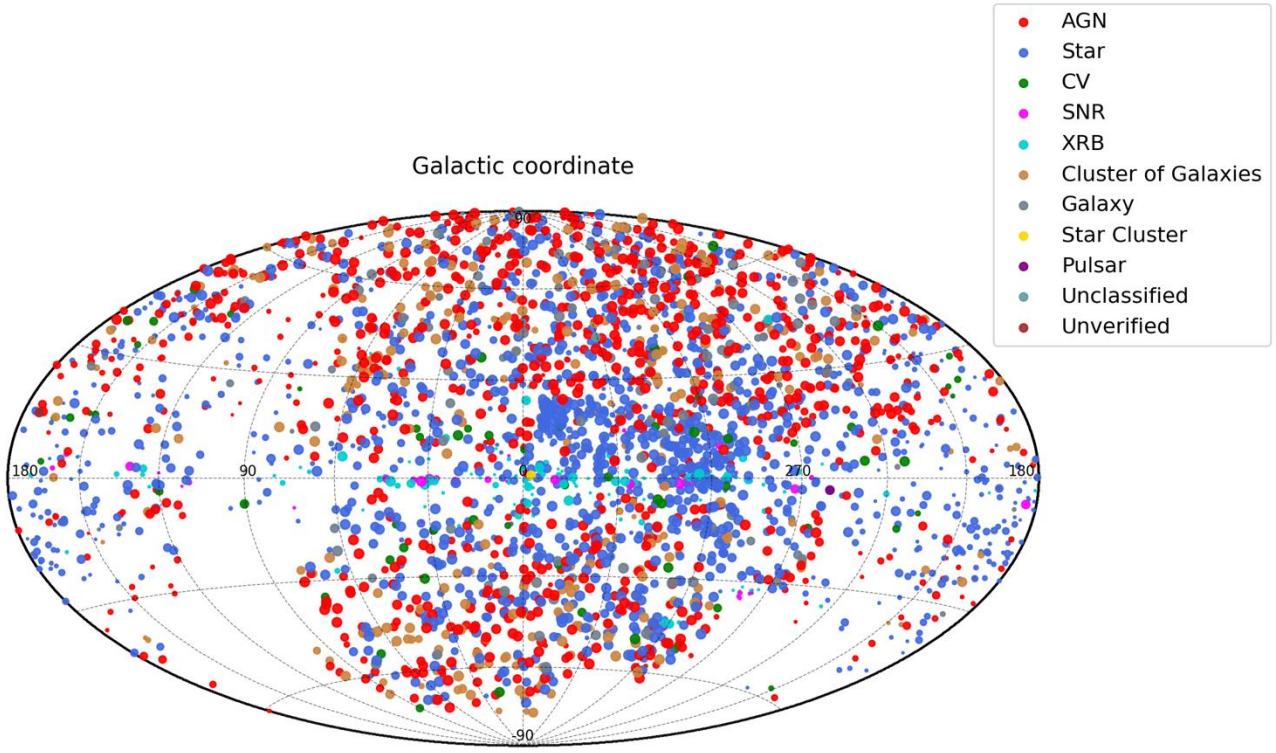


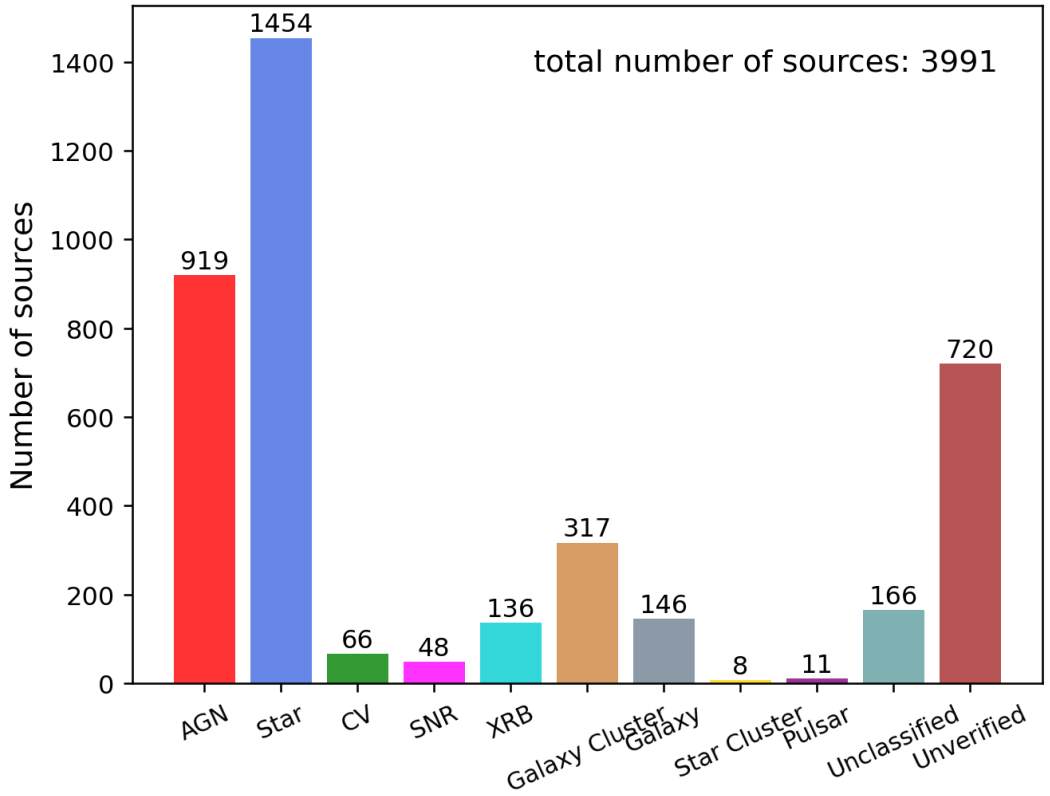
Beidou Alert: 01708918013 CMOS14

RA, Dec	19.907, -68.695	Galactic l, b	299.095, -48.223
RA (HMS), Dec (DMS)	01h19m37.7s,-68d41m42.0s	1 σ Pos Err (arcmin)	0.692
Observation Time (UTC)	2024-06-05 16:00:40	Trigger Time (UTC)	2024-06-05 16:10:30
X	2674.2	Y	3576.6
Net Rate	0.06	Variance	13.34
Significance	8.1	HR	0.18



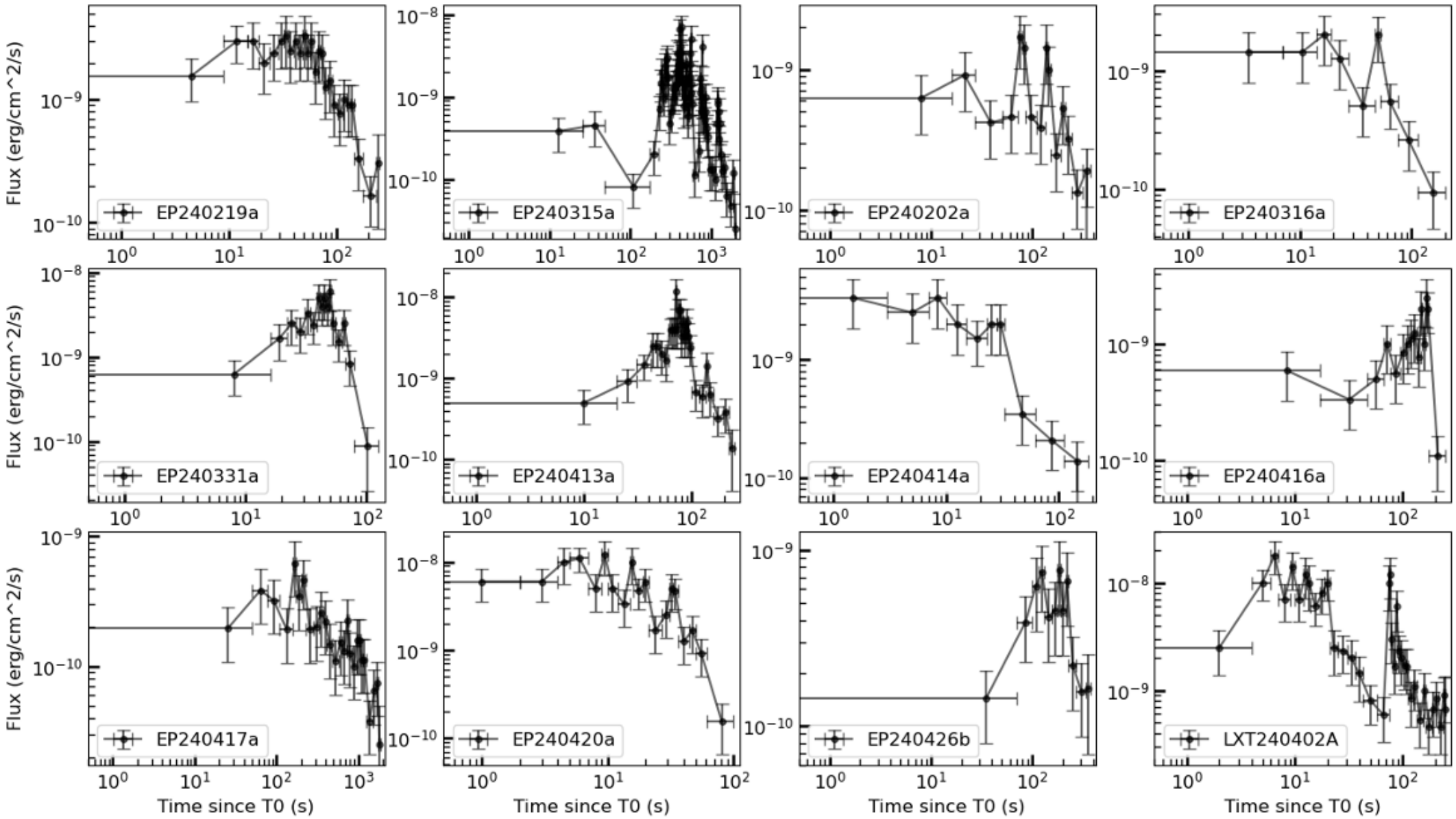
Statistics on X-ray sources detected with EP-WXT





- WXT：known bright sources detected: ~5000
- FXT：More than 13,000 new sources found
- Transients：> 45 high S/N (> 100 low S/N)
- Stellar flares：340
- ~ 60 GCN+Atel alerts

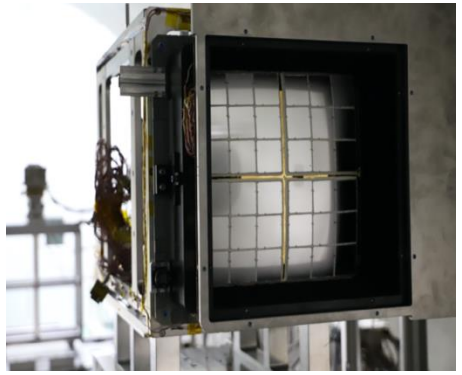
快速暂现源 X 射线光变曲线 （举例、高信噪比）



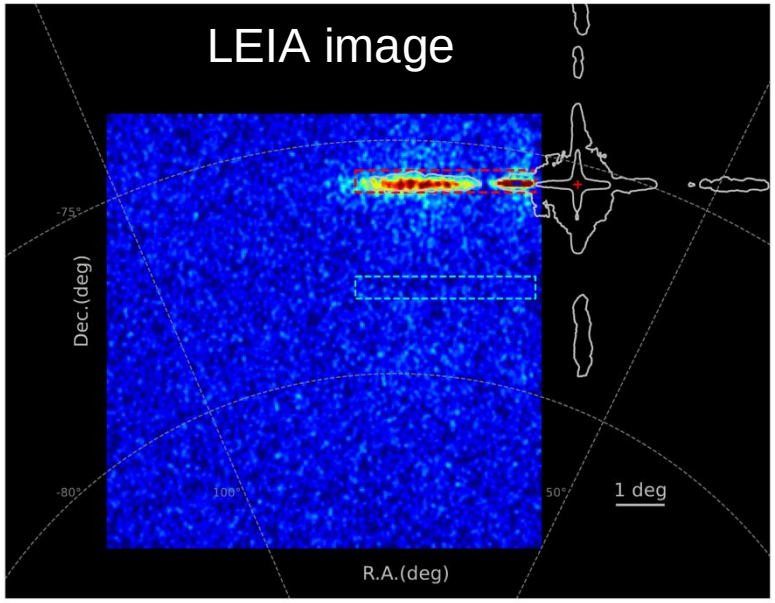
Examples of fast X-ray transients by EP & LEIA

Transient	Duration	Peak Flux erg $cm^{-2}s^{-1}$	Fluence erg cm^{-2}	γ-ray counterpart	X-ray afterglow	Optical afterglow	z
LXT/GRB 230307A	~180 s	4E-7	2E-5	Y	Y	Y	0.065
EP240219a	~200 s	5E-9	1E-7	Y	X	N	-
EP240315a	~1600 s	3E-9	1E-6	Y	Y	Y	4.859
EP240202a	~300 s	4E-9	9E-8	N	N	N	-
EP240316a	~160 s	3E-9	1E-7	N	N	N	-
EP240331a	~100 s	4E-9	2E-7	N	possible?	N	-
LXT240402a	~200 s	3E-8	5E-7	Y	Y	Y	1.551
EP240413a	~200 s	7E-9	2E-7	N	possible?	N	-
EP240414a	~150 s	3E-9	2E-7	N (GBM off)	Y	Y	0.4
EP240416a	> 200 s	1E-9	1E-7	N (GBM off)	N	N	-
EP240417a	> 1500 s	3E-10	1E-7	N	N	N	-
EP240420a	~80 s	8E-9	3E-7	N	Y	Y	-
EP240426b	~300 s	9E-10	2E-7	N	N	N	-
EP240506a	~50 s	1E-8	5E-8	N	N	N	-

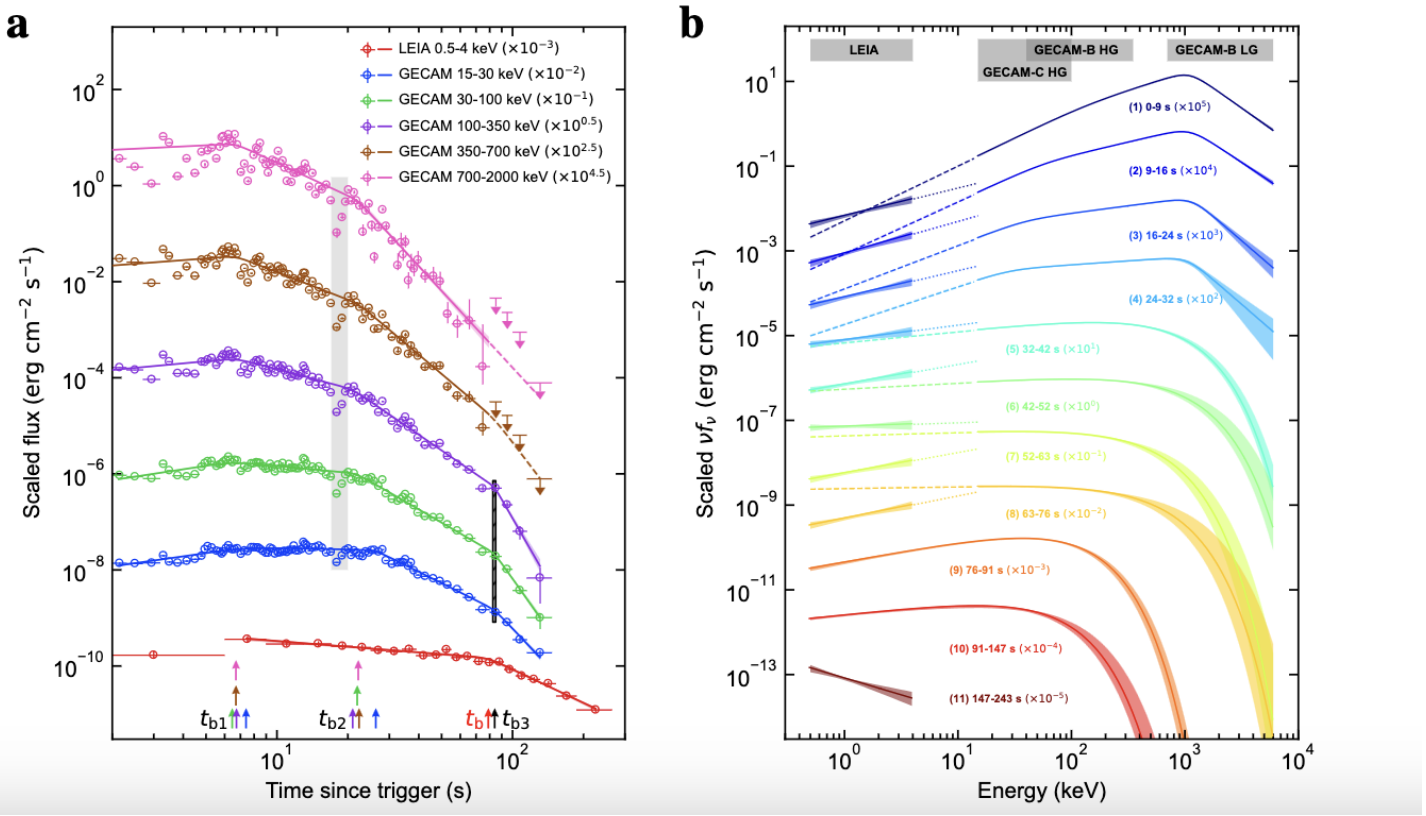
LXT/GRB 230307A



LEIA 0.5 – 4 keV

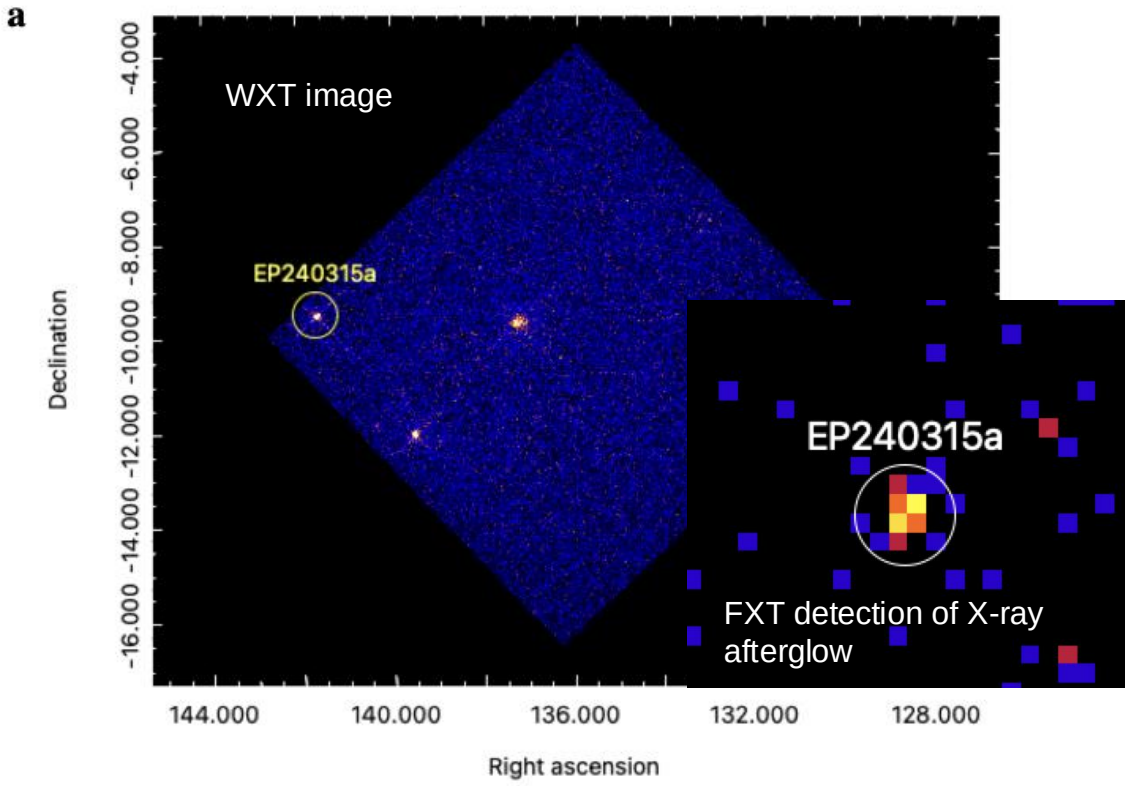


- Hard X-rays and gamma-rays powered by relativistic jet
- Soft X-rays likely powered by a magnetar, emerging from burst onset
- Consistent with the association of kilonova signature found by JWST

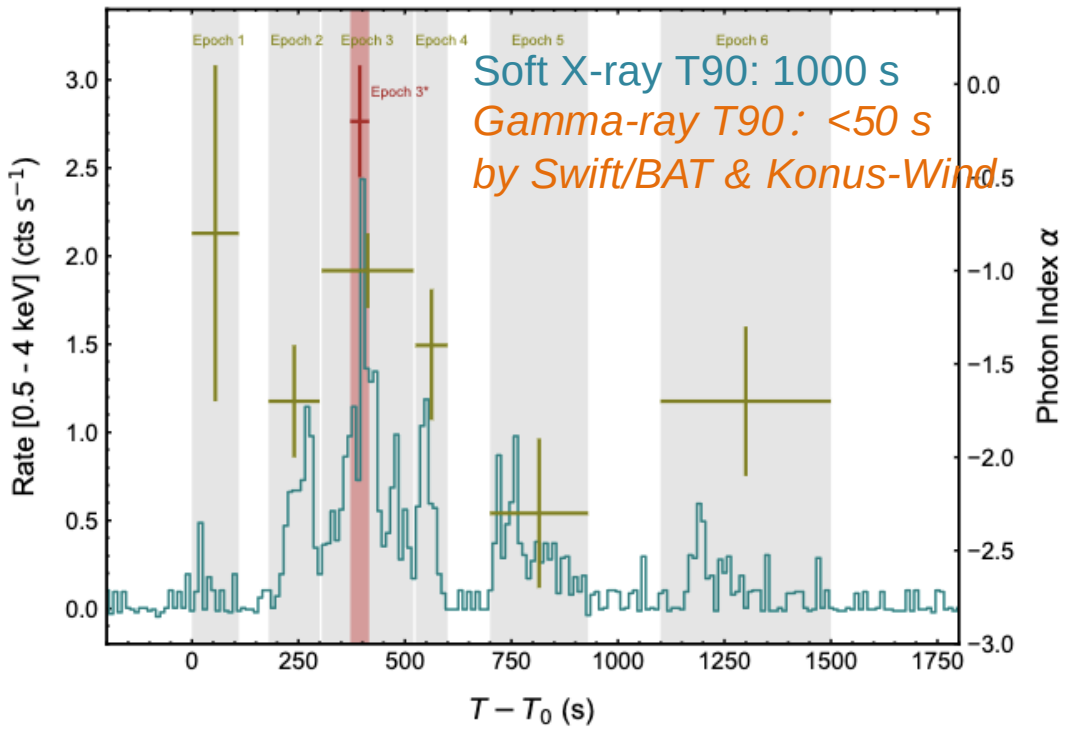


Sun H. et al. NSR. under review arXiv:2307.05689

EP240315a: GRB @redshift 4.859



redshift 4.859 measured by VLT (Levan et al. 2024)
detectable by WXT at z~7.5



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

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)

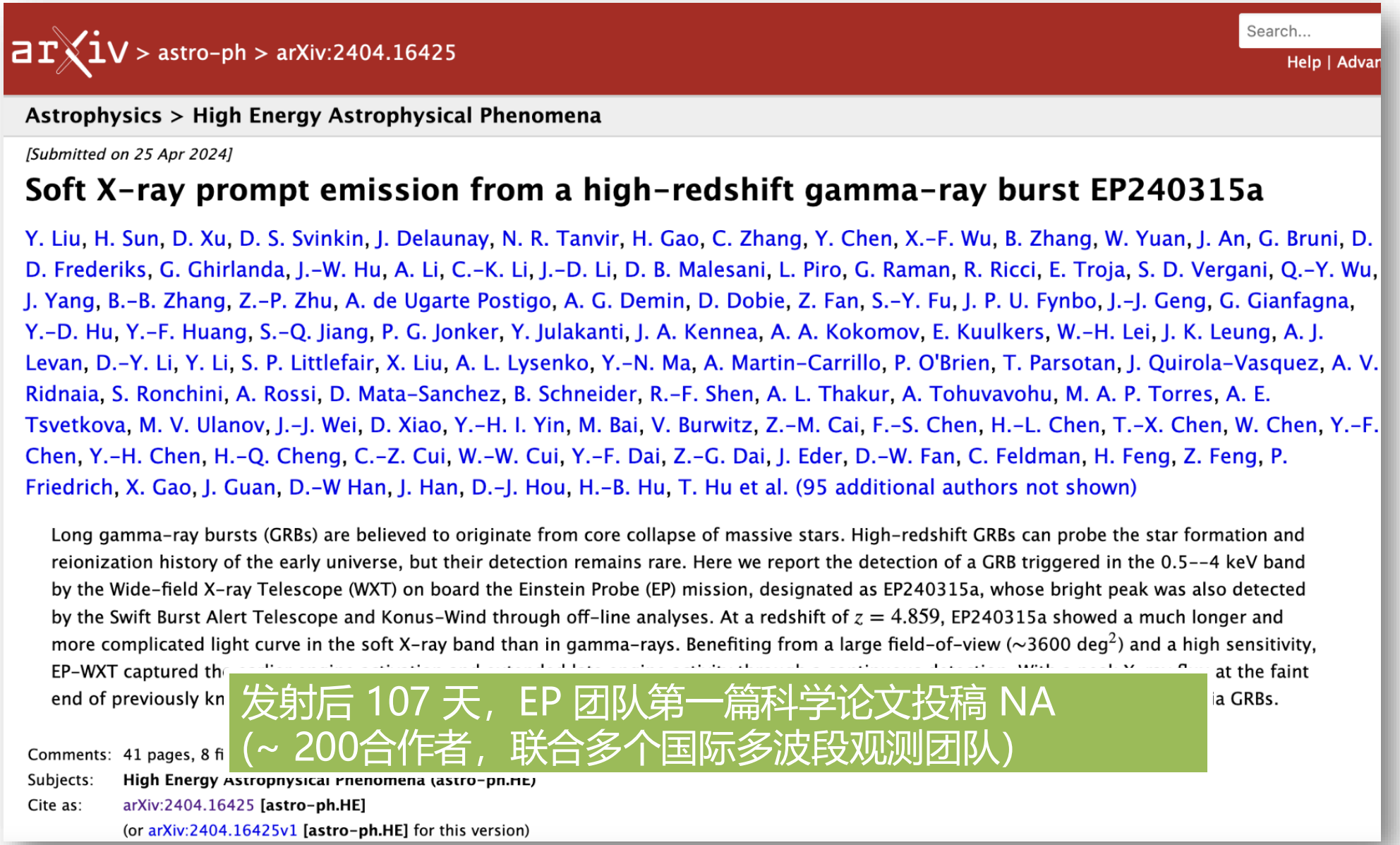
伽玛暴研究的机遇： 软 X 射线波段 + 最高的监测灵敏度

EP240315a：引导国际上多个大型望远镜后随观测

- Swift/BAT, Konus Wind (gamma-ray)
- EP-FXT, Chandra (X-ray)
- ATLAS, VLT, GTC (optical)
- GROND, TNG, WIRC (IR)
- MeerKAT, ATCA, e-MERLIN (radio)

28 GCN Circulars

EP240315a： 伽马射线暴 @红移 ~4.8



arXiv > astro-ph > arXiv:2404.16425

Search... Help | Advar

Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 25 Apr 2024]

Soft X-ray prompt emission from a high-redshift gamma-ray burst EP240315a

Y. Liu, H. Sun, D. Xu, D. S. Svinkin, J. Delaunay, N. R. Tanvir, H. Gao, C. Zhang, Y. Chen, X.-F. Wu, B. Zhang, W. Yuan, J. An, G. Bruni, D. D. Frederiks, G. Ghirlanda, J.-W. Hu, A. Li, C.-K. Li, J.-D. Li, D. B. Malesani, L. Piro, G. Raman, R. Ricci, E. Troja, S. D. Vergani, Q.-Y. Wu, J. Yang, B.-B. Zhang, Z.-P. Zhu, A. de Ugarte Postigo, A. G. Demin, D. Dobie, Z. Fan, S.-Y. Fu, J. P. U. Fynbo, J.-J. Geng, G. Gianfagna, Y.-D. Hu, Y.-F. Huang, S.-Q. Jiang, P. G. Jonker, Y. Julakanti, J. A. Kennea, A. A. Kokomov, E. Kuulkers, W.-H. Lei, J. K. Leung, A. J. Levan, D.-Y. Li, Y. Li, S. P. Littlefair, X. Liu, A. L. Lysenko, Y.-N. Ma, A. Martin-Carrillo, P. O'Brien, T. Parsotan, J. Quirola-Vasquez, A. V. Ridnaia, S. Ronchini, A. Rossi, D. Mata-Sanchez, B. Schneider, R.-F. Shen, A. L. Thakur, A. Tohuvavohu, M. A. P. Torres, A. E. Tsvetkova, M. V. Ulanov, J.-J. Wei, D. Xiao, Y.-H. I. Yin, M. Bai, V. Burwitz, Z.-M. Cai, F.-S. Chen, H.-L. Chen, T.-X. Chen, W. Chen, Y.-F. Chen, Y.-H. Chen, H.-Q. Cheng, C.-Z. Cui, W.-W. Cui, Y.-F. Dai, Z.-G. Dai, J. Eder, D.-W. Fan, C. Feldman, H. Feng, Z. Feng, P. Friedrich, X. Gao, J. Guan, D.-W Han, J. Han, D.-J. Hou, H.-B. Hu, T. Hu et al. (95 additional authors not shown)

Long gamma-ray bursts (GRBs) are believed to originate from core collapse of massive stars. High-redshift GRBs can probe the star formation and reionization history of the early universe, but their detection remains rare. Here we report the detection of a GRB triggered in the 0.5--4 keV band by the Wide-field X-ray Telescope (WXT) on board the Einstein Probe (EP) mission, designated as EP240315a, whose bright peak was also detected by the Swift Burst Alert Telescope and Konus-Wind through off-line analyses. At a redshift of $z = 4.859$, EP240315a showed a much longer and more complicated light curve in the soft X-ray band than in gamma-rays. Benefiting from a large field-of-view (~3600 deg^2) and a high sensitivity, EP-WXT captured th… at the faint end of previously kn… a GRBs.

发射后 107 天，EP 团队第一篇科学论文投稿 NA
(~ 200合作者，联合多个国际多波段观测团队)

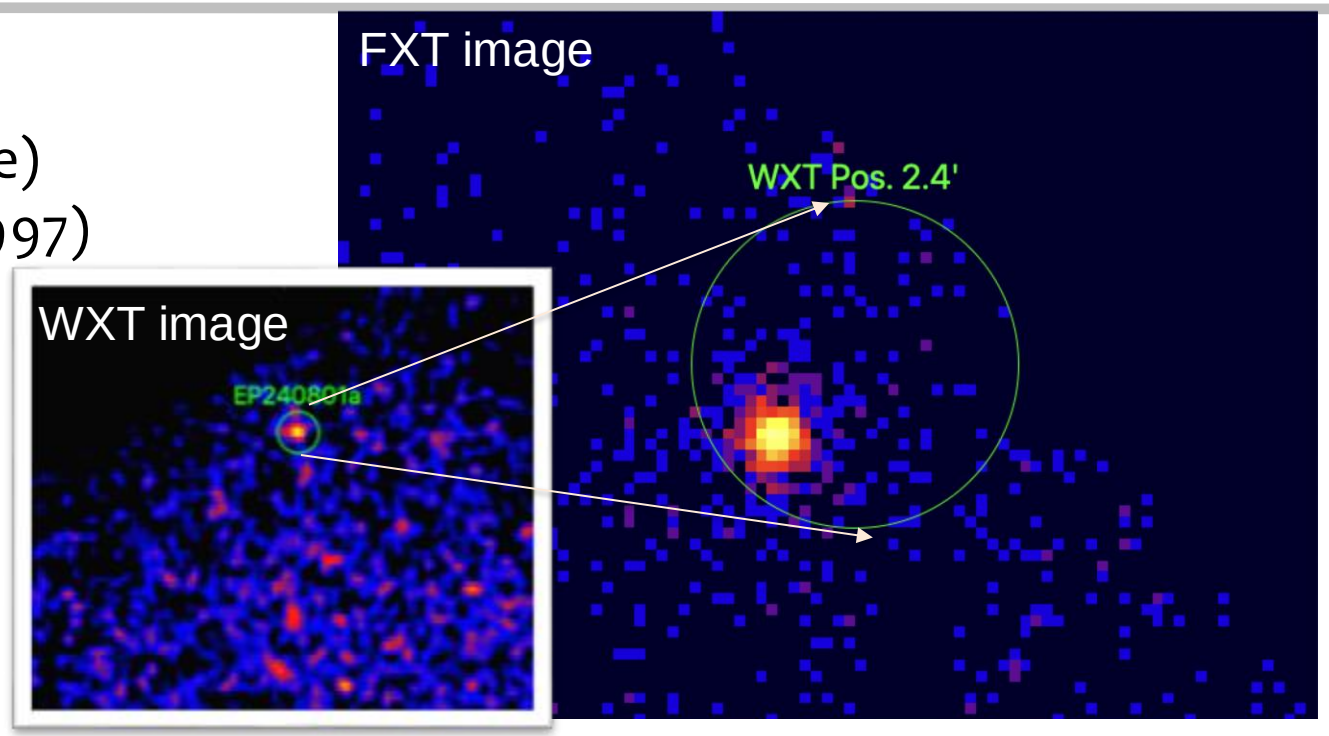
Comments: 41 pages, 8 fi…
Subjects: High Energy Astrophysical Phenomena (astro-ph.HE)
Cite as: arXiv:2404.16425 [astro-ph.HE]
(or arXiv:2404.16425v1 [astro-ph.HE] for this version)

EP240801a: first GRB with autonomous FXT follow-up observation

- WXT onboard trigger (GCN notice)
- FXT follow-up: T0+180s (GCN 36997)

- optical follow-up:

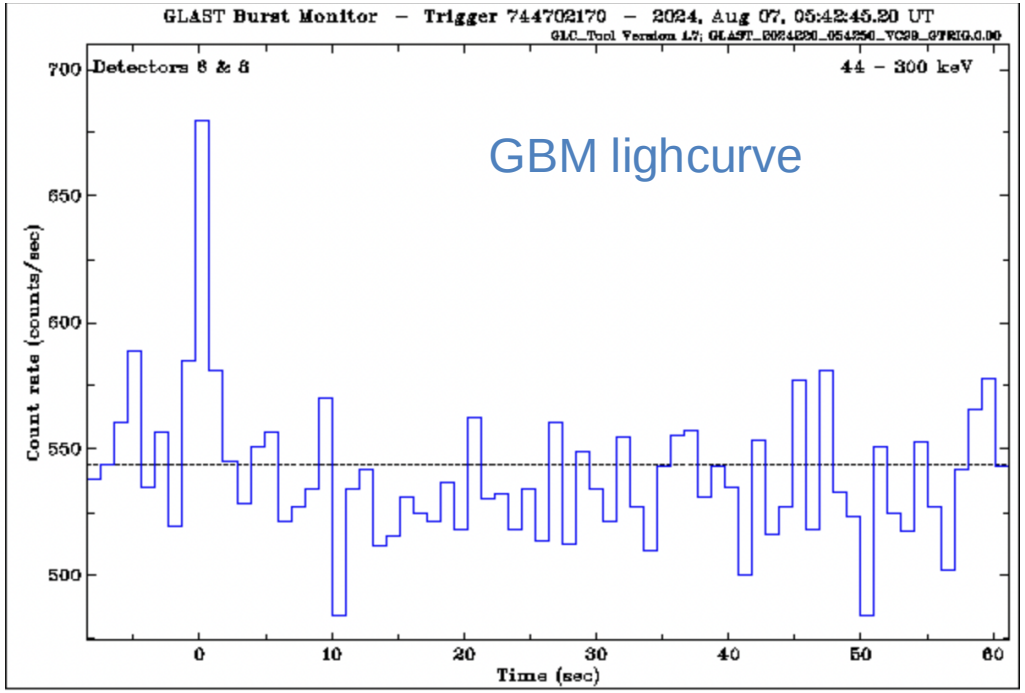
  KAIT, T0+0.41h, R~19.86,mag
  GSP, T0+1.3 h
  TRT, T0+2.24h
  GMG , T0+7.22h
  LCOGT, T0+7.65h
  Jinshan, T0+9.63
  LCOGT, T0+7.65h
  NOT, T0+13.56h
  SAO RAS, T0+15.32
  ……
  redshift: z=1.673, T0+0.79d (GCN 37013)
  ……

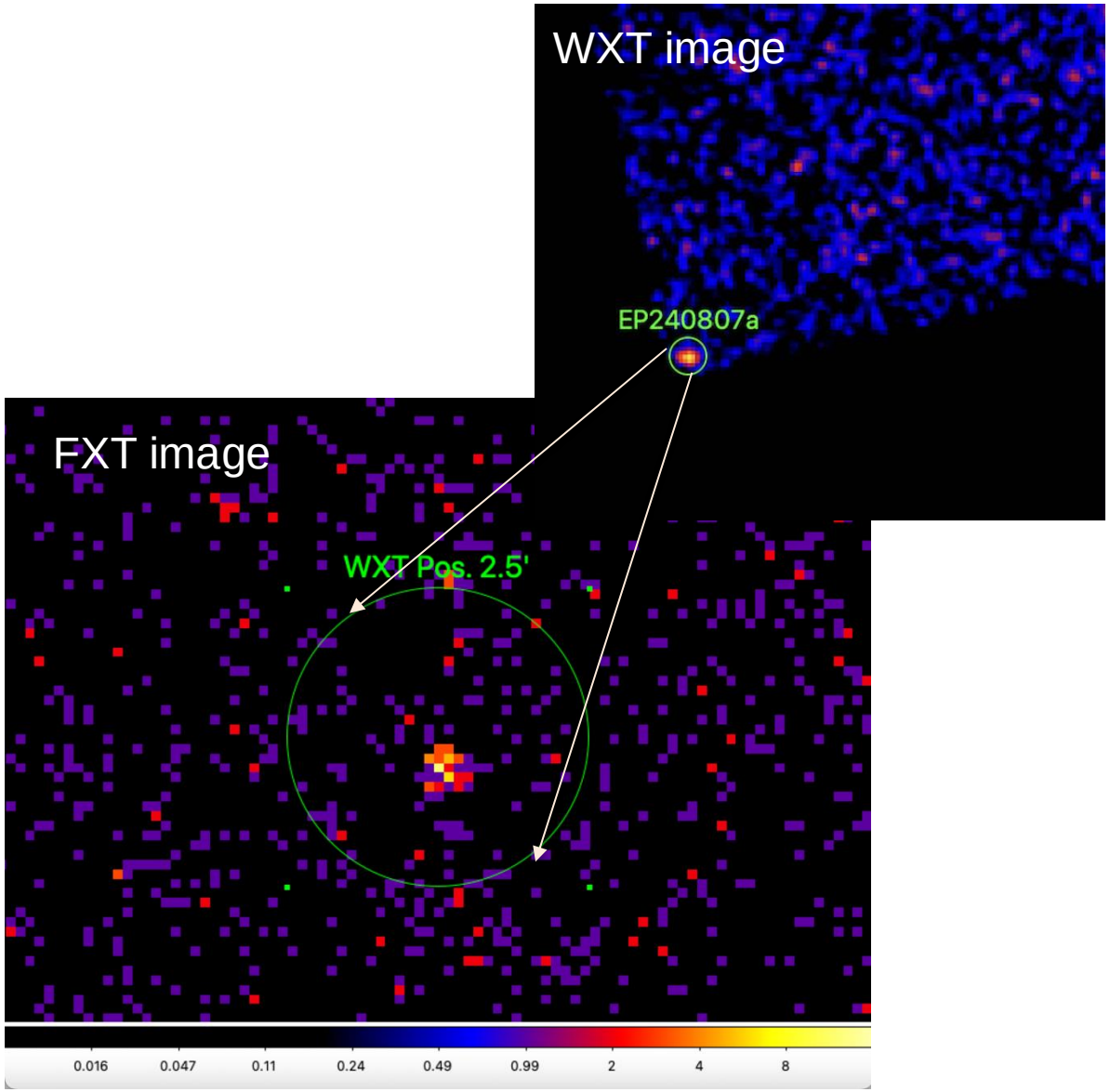


37049. EP240801a: BTA BVRI photometry
37040. EP240801a: Continued optical observations at ZTSh (CraO)
37024. EP240801a: Osservatorio Astronomico Nastro Verde upper limit
37017. EP240801a: further SAO RAS optical observations
37016. EP240801a: optical observations at CrAO and AbAO
37015. EP240801a: GRANDMA and Kilonova-Catcher optical observations
37014. EP240801a: Leavitt Observatory optical observations
37013. EP240801a: GTC spectroscopy and absorption redshift
37012. EP240801a: SAO RAS optical observations
37010. EP240801a: JinShan optical observations
37008. EP240801a: NOT optical observations
37007. EP240801a: follow-up observation with LCOGT
37004. EP240801a: GSP follow-up observations of the candidate counterpart
37002. EP240801a: Kinder follow-up observations of the candidate counterpart
37000. EP240801a: KAIT optical counterpart observations
36999. EP240801a: GMG observation
36998. EP240801a: TRT optical counterpart detection
36997. EP240801a: EP-WXT detection and EP-FXT follow-up observation of a fast X-ray transient

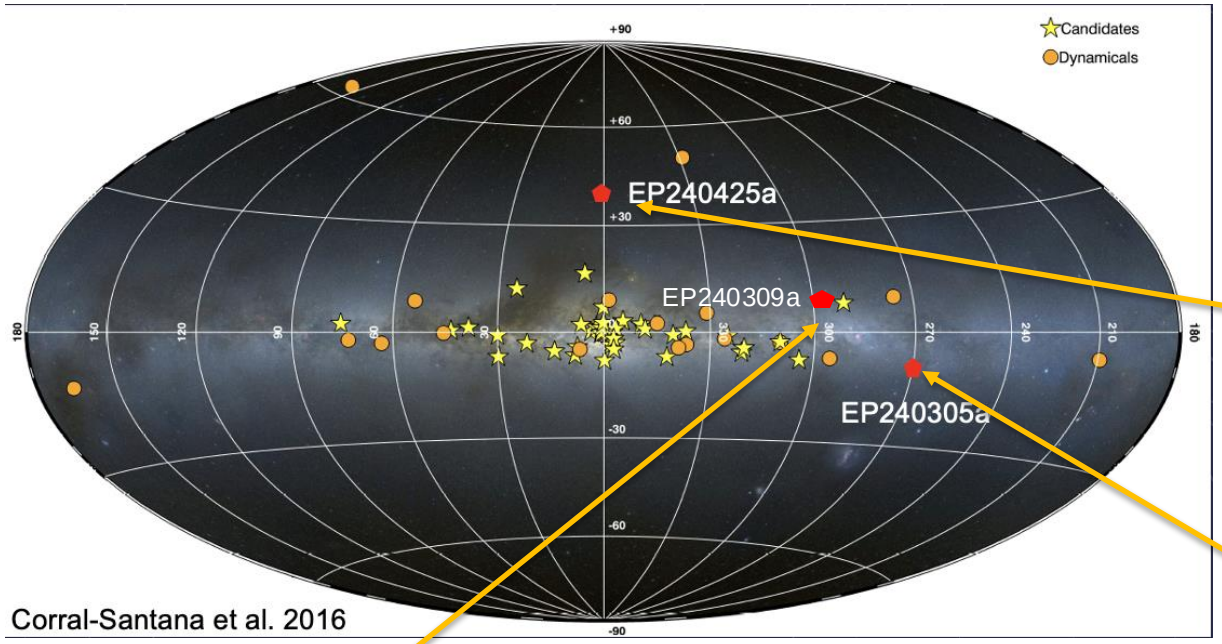
EP240807a: likely short GRB

- WXT ground pipeline (GCN 37088)
  duration: ~70s
- FXT follow-up: To+7.7h (GCN 37097)
- GBM detection, GCN 37089
  likely short GRB

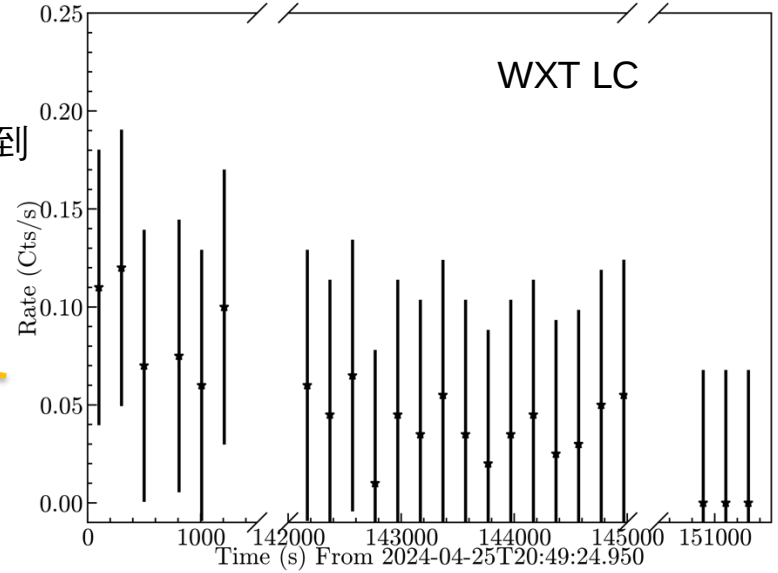




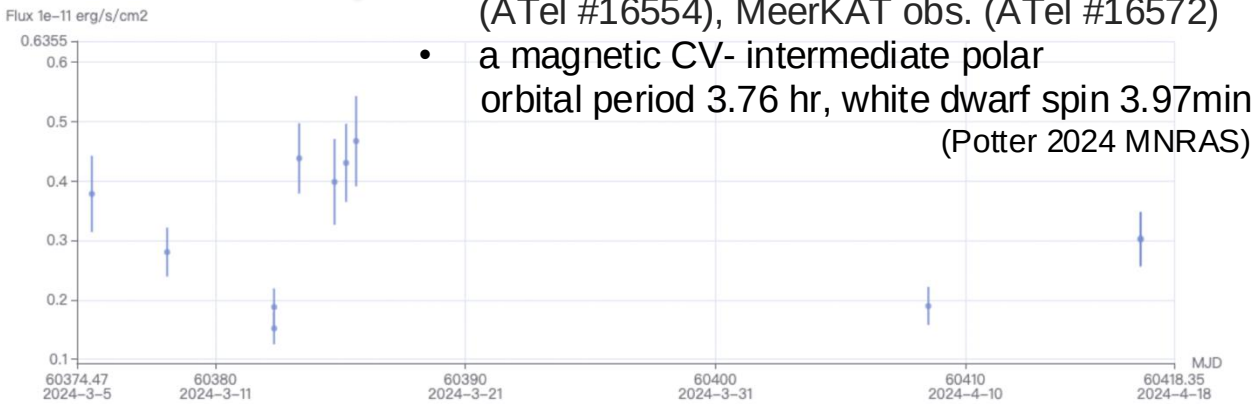
Galactic transients

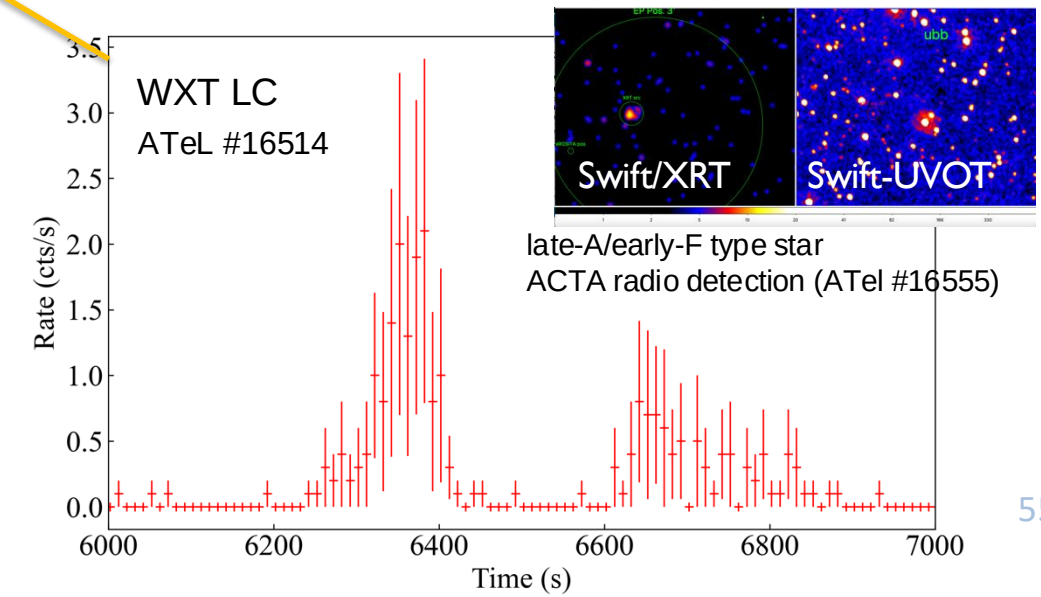


射电探测到
喷流结构

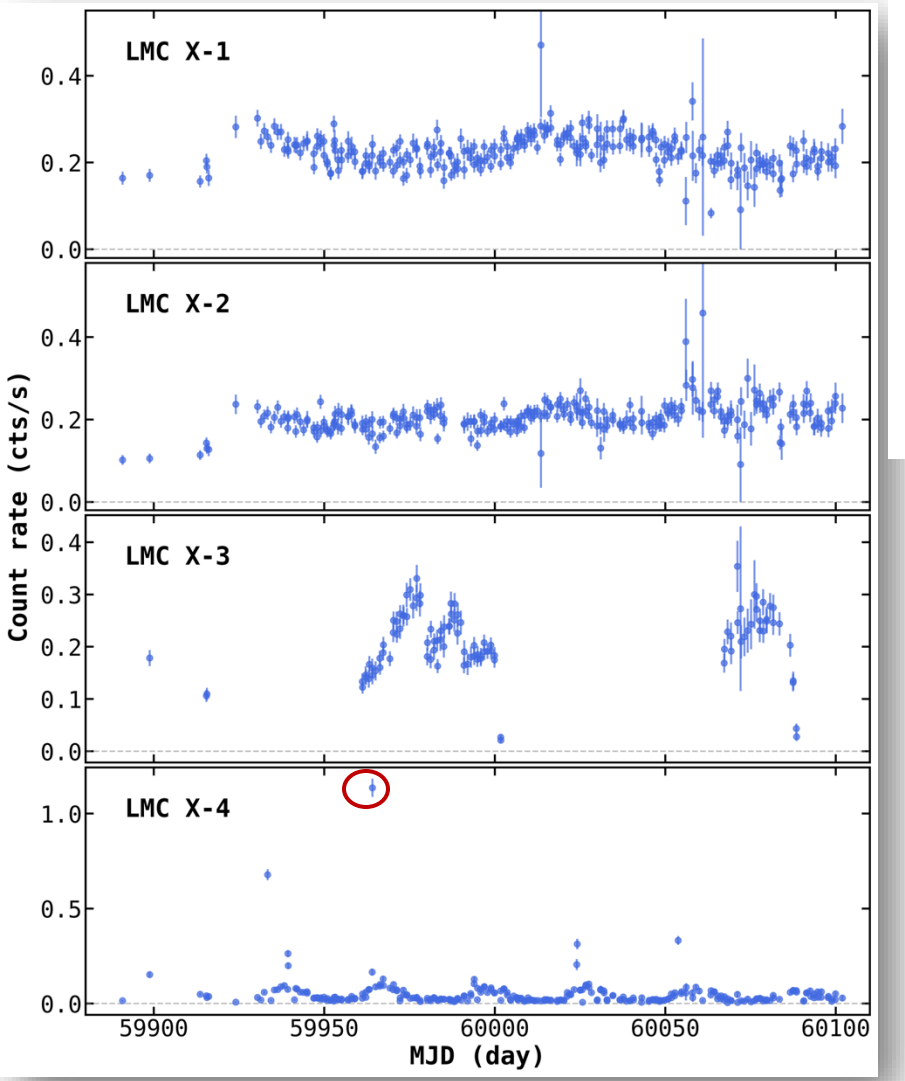


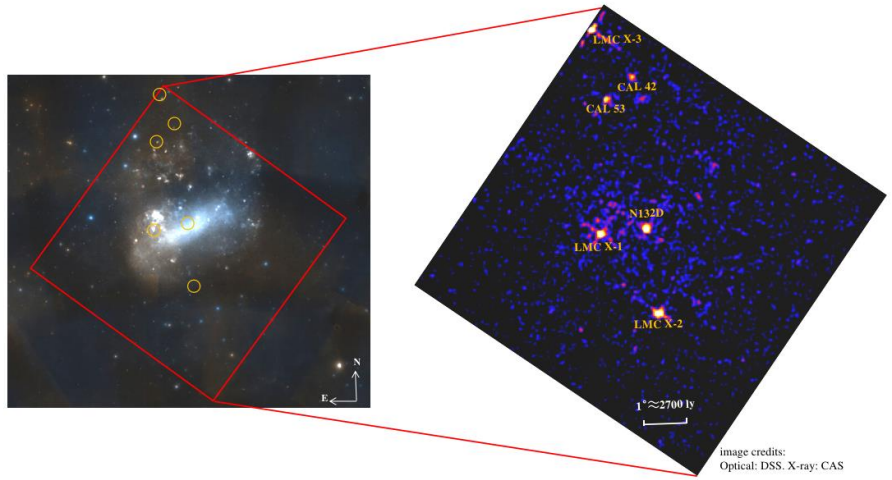
- A bright UV source and highly variable in optical (ATel #16554), MeerKAT obs. (ATel #16572)
- a magnetic CV- intermediate polar
  orbital period 3.76 hr, white dwarf spin 3.97min
  (Potter 2024 MNRAS)





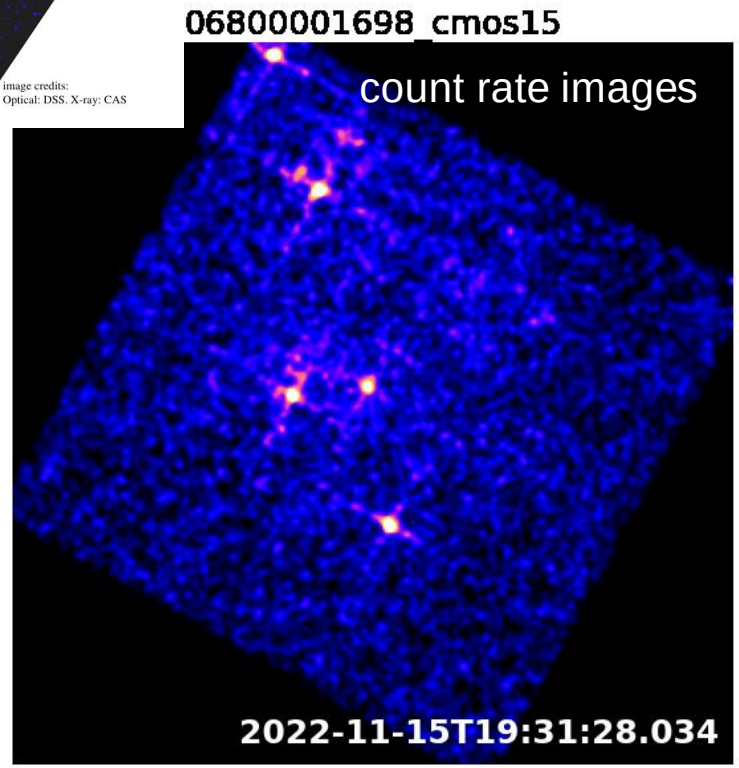
LEIA's monitoring of LMC (> 200 days)

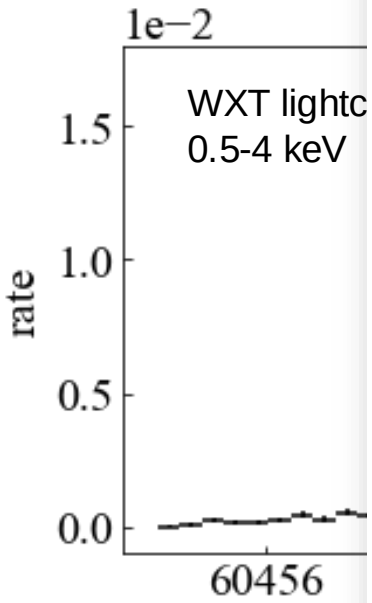




1 CMOS
(1/4 FoV of LEIA)

- *LEIA is still operational and keeps making discoveries!*
- *though 2/4 CMOS working abnormally*





Draft version July 29, 2024
Typeset using LaTeX default style in AASTeX631

Einstein Probe discovery of a super-soft outburst from CXOU J005245.0−722844: a rare BeWD binary in the Small Magellanic Cloud

A. Marino [1,2] H. N. Yang [3,4,5] F. Coti Zelati [1,2] N. Rea [1,2] S. Guillot [6] G. K. Jaisawal [7] C. Maitra [4] F. Haberl [4] E. Kuulkers [8] W. Yuan,[3,5] H. Feng,[9] L. Tao,[9] C. Jin,[3,5] H. Sun [3] W. Zhang,[3] W. Chen,[3,5] E. P. J. van den Heuvel,[10] R. Soria [11,12,13] B. Zhang [14,15] S-S. Weng,[16] L. Ji,[17] G. B. Zhang,[18] X. Pan,[3] Z. Lv,[3,5] C. Zhang,[3,5] Z. X. Ling,[3,5] Y. Chen,[9] S. Jia,[9,5] Y. Liu,[3] J.-U. Ness [19] H. Q. Cheng,[3] D. Y. Li,[3] K. Gendreau [20] and M. Ng [21]

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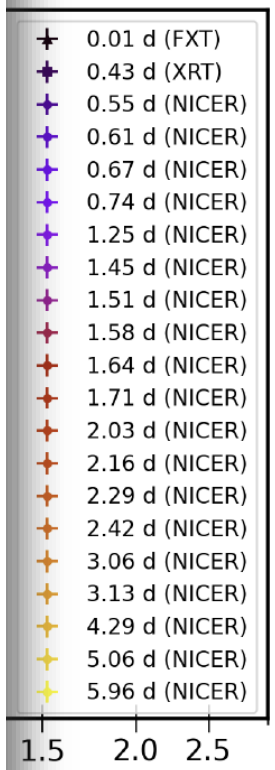
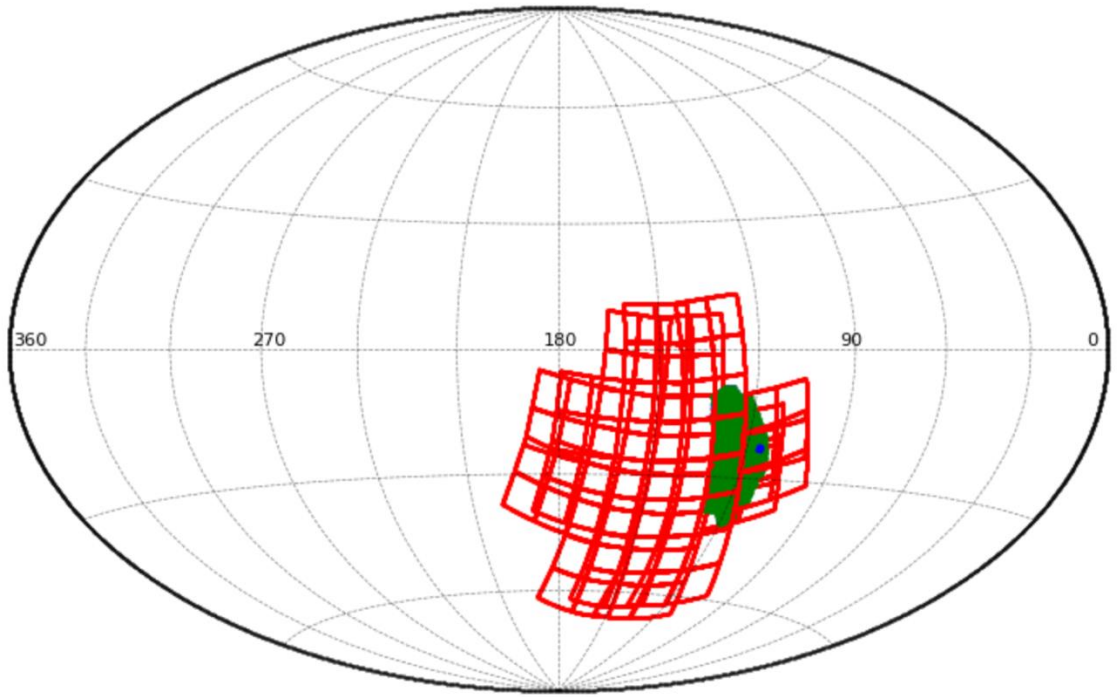
NICER (ATeL# 16636)

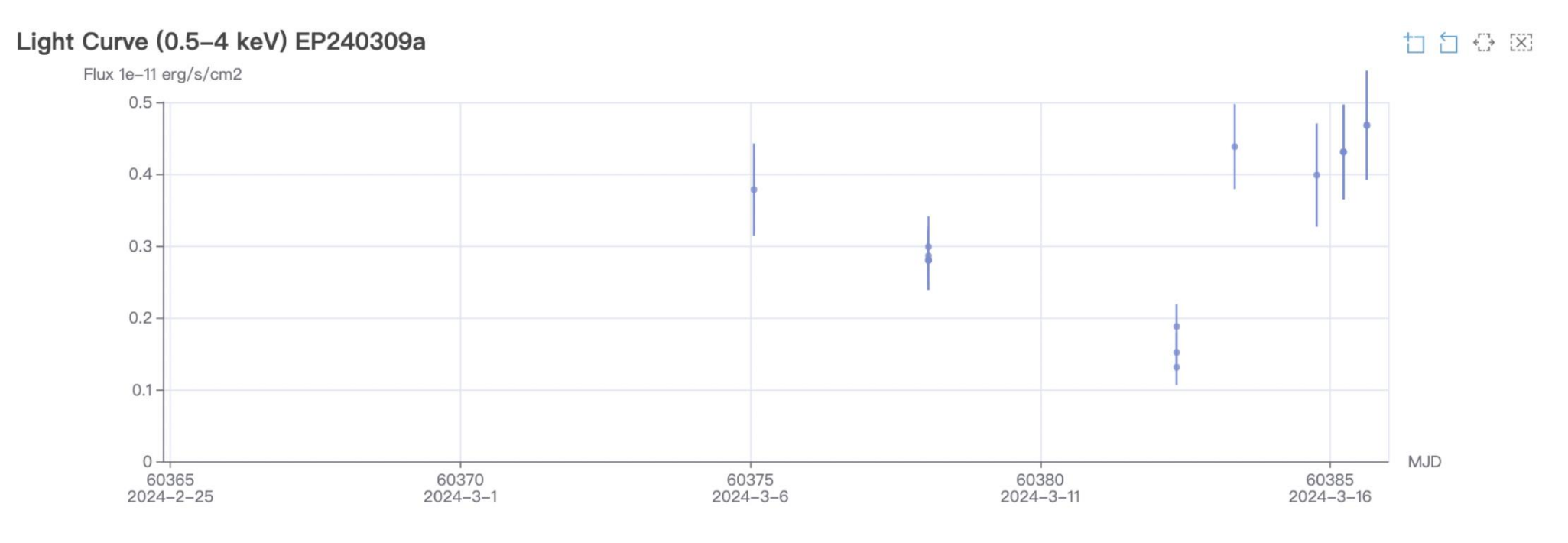


搜寻引力波事件 S240422ed 的 X 射线对应体

- 中子星-黑洞并合事件 距离 214 +/- 64 Mpc
- WXT 给出了软 X射线强度限制（GCN: 36270, 36277, 36282)
- FXT 给出了天区中几十个星系的 X 射线更强的限制



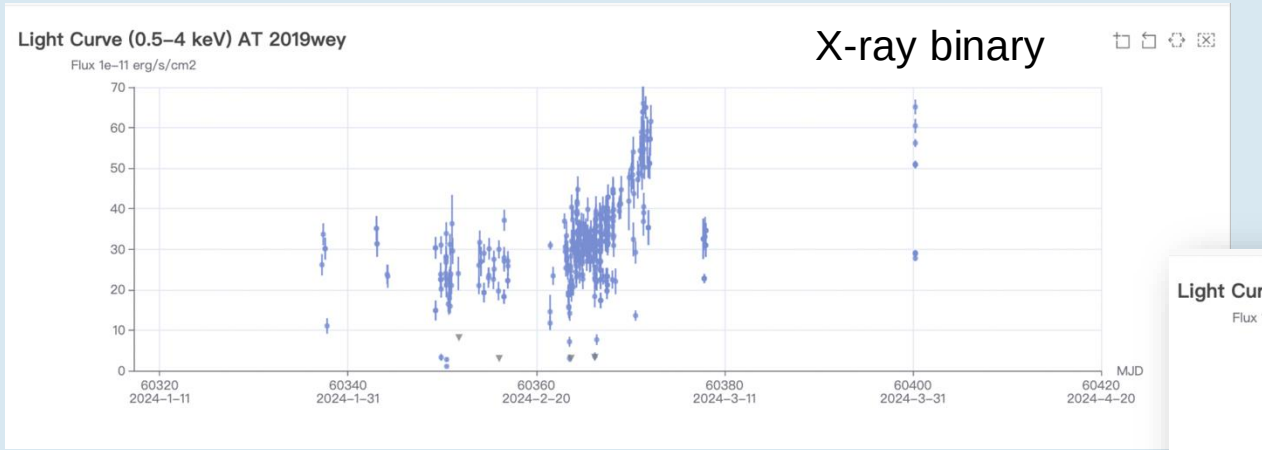
EP240309a: long-timescale X-ray transient



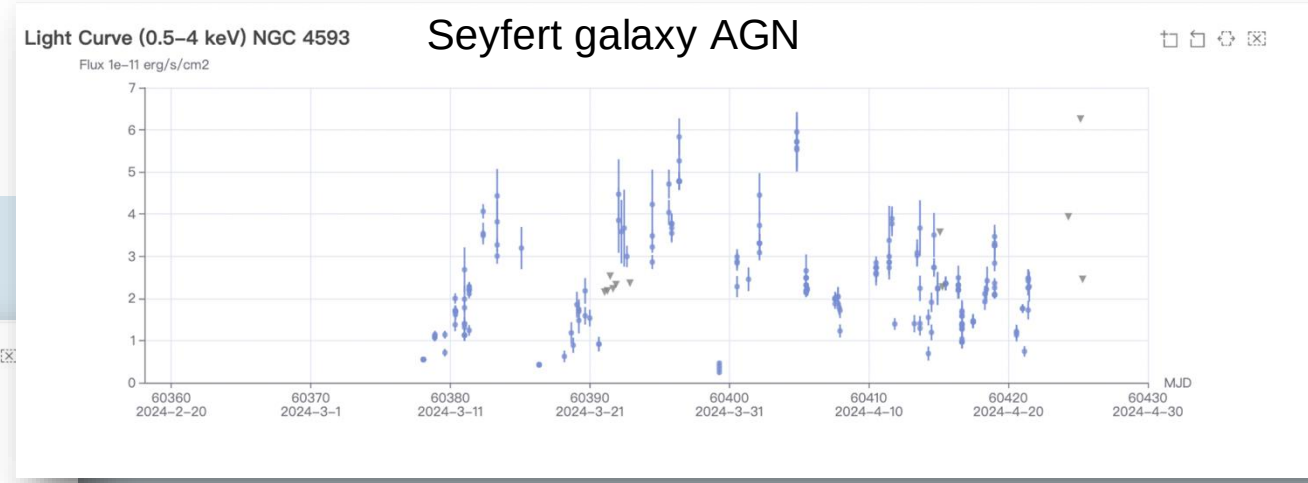
- FXT follow-up
- A bright UV source with a highly variable optical counterpart
- SALT spectrum, (ATel #16554), MeerKAT observation (ATel #16572)

a magnetic cataclysmic variable containing a white dwarf (Potter et al.)

Monitoring of known X-ray sources



X-ray binary



Seyfert galaxy AGN

blazar

EP 对 IceCube-Cascade 240714A 的X 射线对应体搜寻

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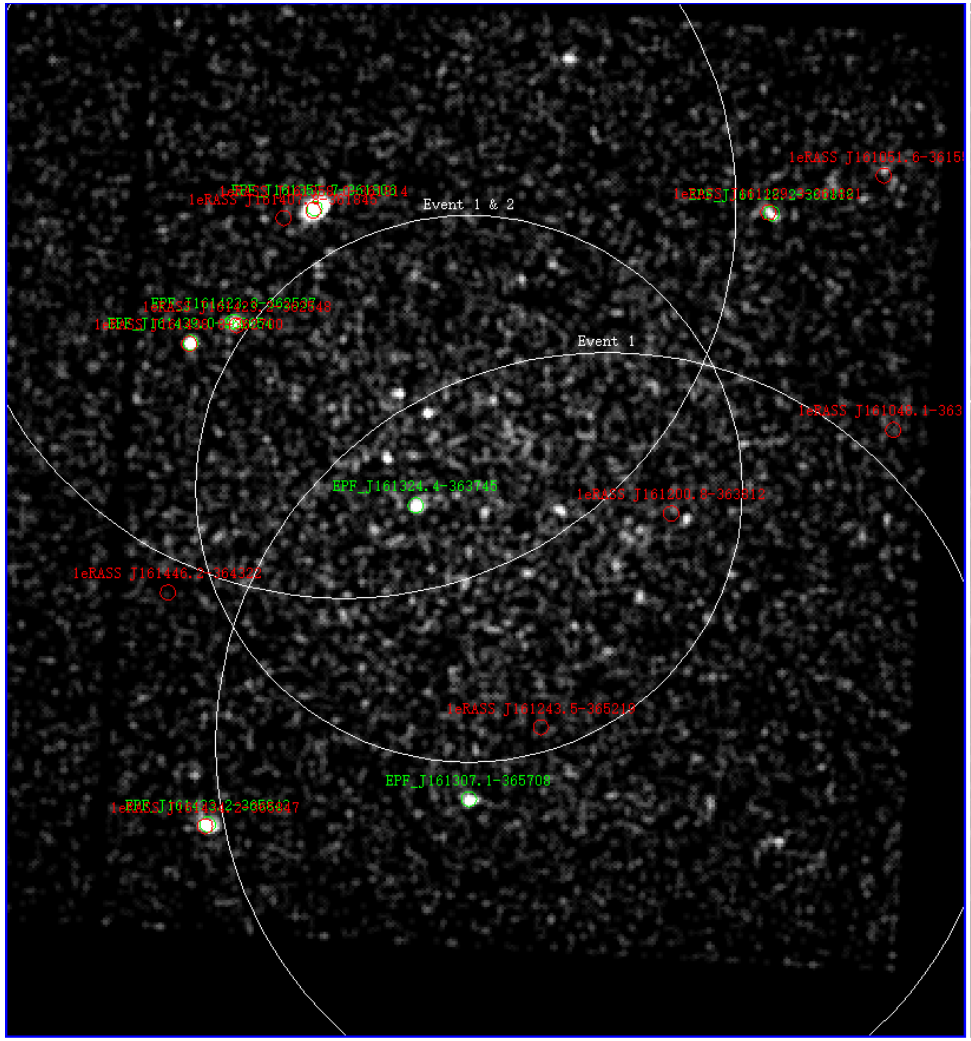

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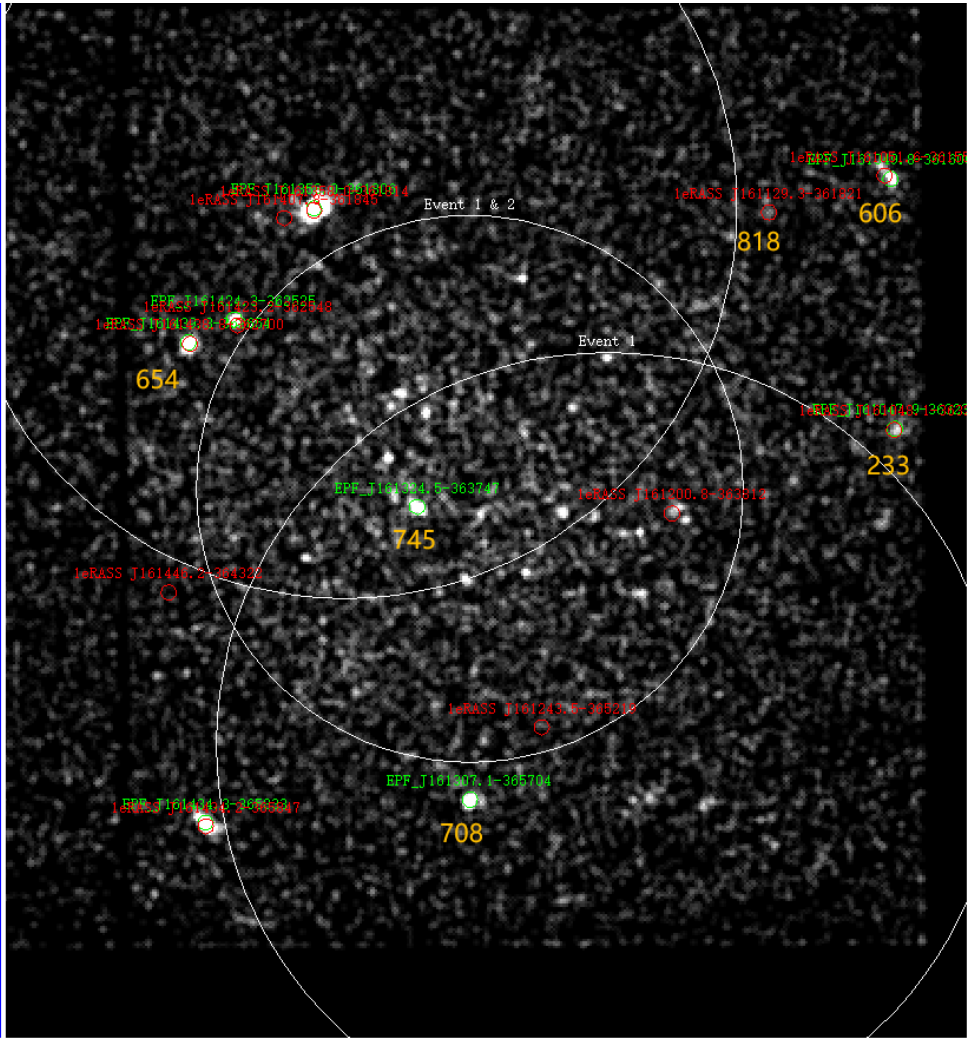
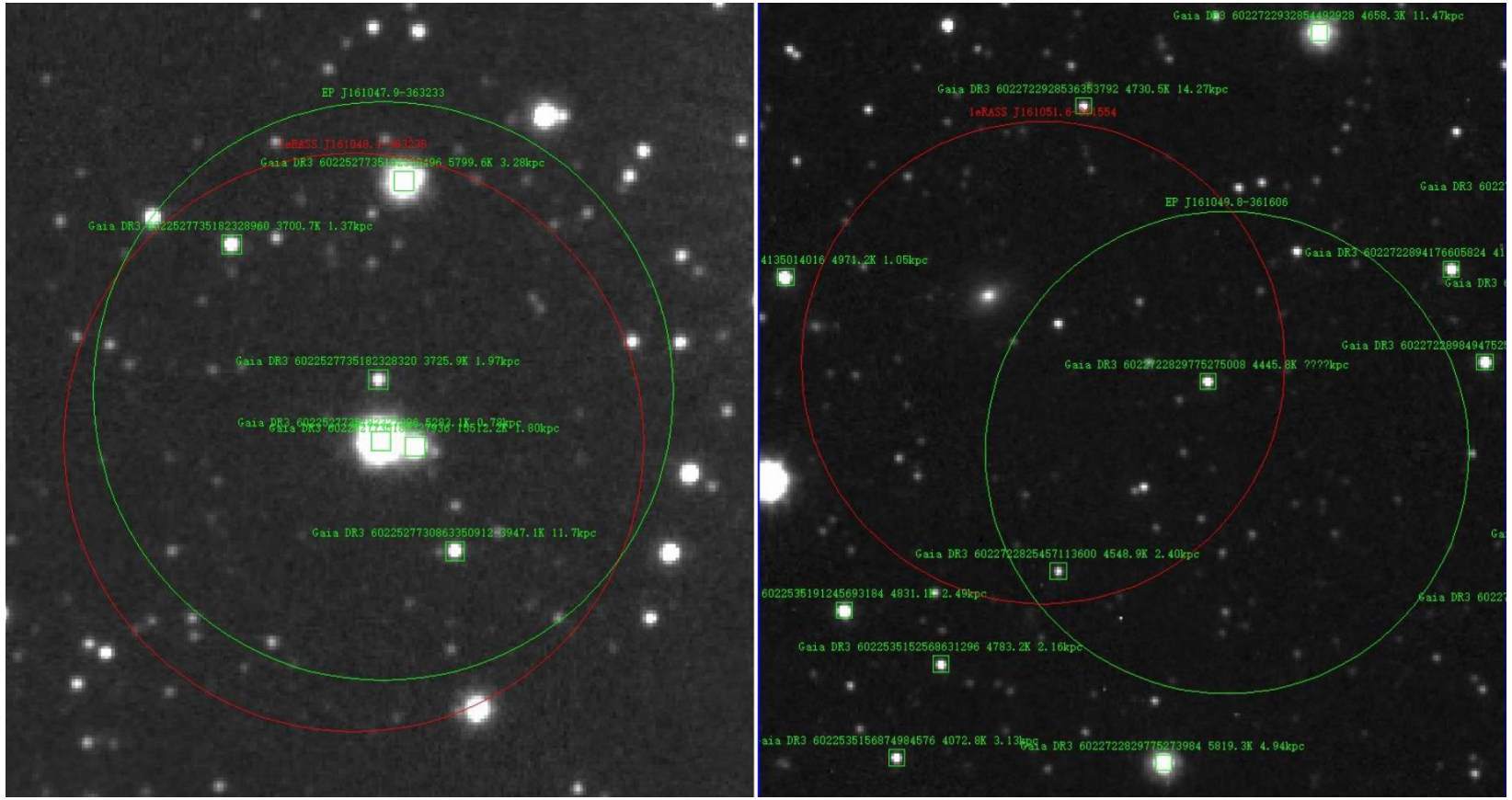
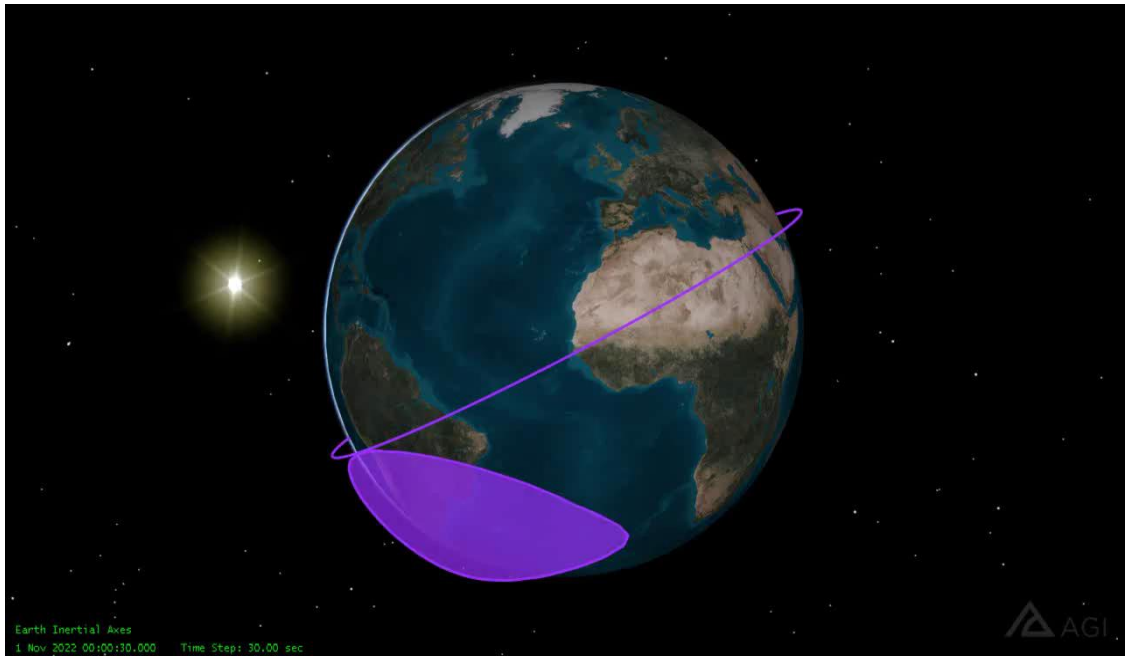


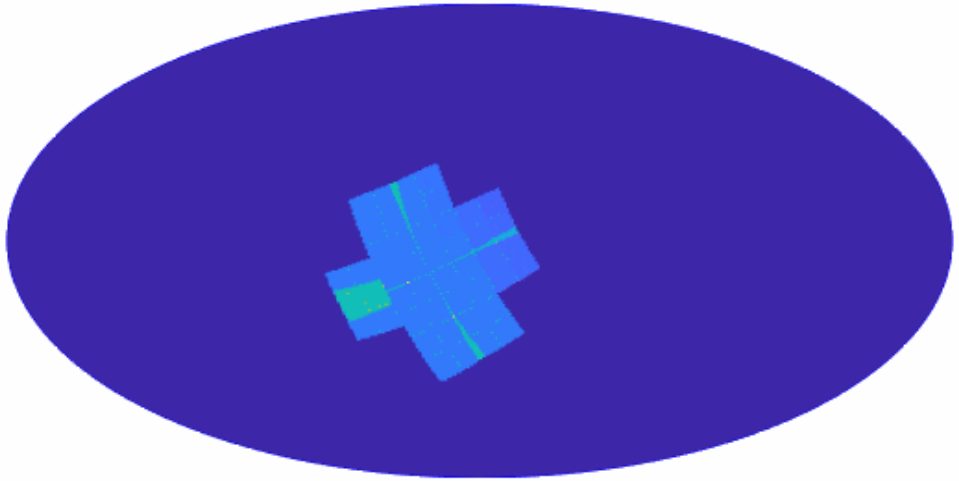
EP 对 IceCube-Cascade 240714A 的X 射线对应体搜寻



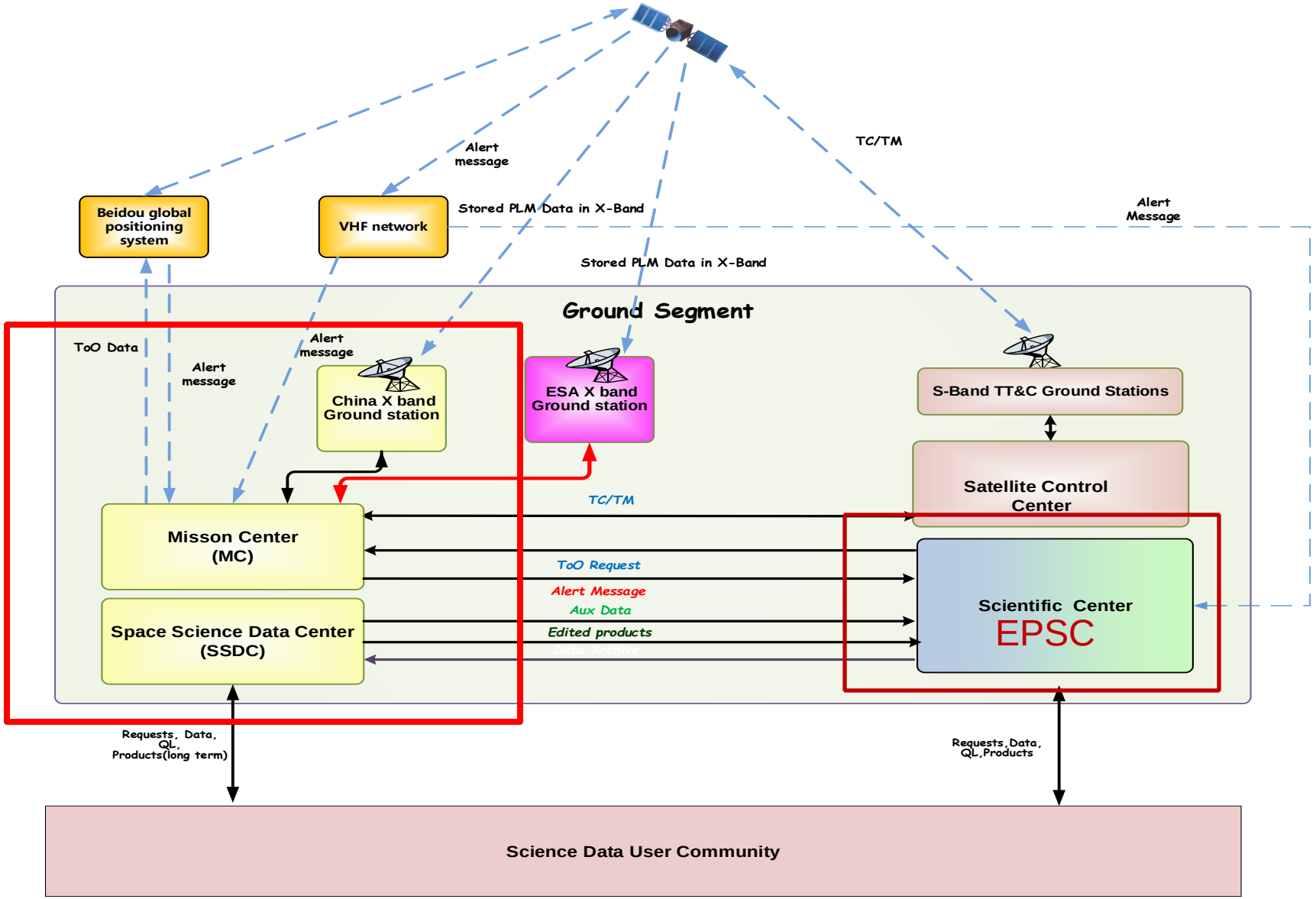
Observation modes

- 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**





EP data and information flows



结语

- 在轨测试定标结果表明：EP 卫星和载荷功能性能指标达到或超过设计要求
- 载荷定标观测预期 6 月底结束，7 月初转入常规观测阶段
- 已经完成了科学团队和科学观测的准备
- 尝试性取得了首批的科学探测结果
- EP 卫星未来的科学发现前景可观

谢谢！