



中国科学院
CHINESE ACADEMY OF SCIENCES



天关的科学能力和对恒星耀发的观测情况



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中国科学院国家天文台

天关科学中心



Q1: 天关卫星的优势是什么？

爱因斯坦探针 Einstein Probe

中国主导的国际合作，欧空局、德国马普所、法宇航



宽场 X 射线望远镜 WXT
视场 >3600 平方度



后随 X 射线望远镜 FXT



星上暂现源自动搜寻、卫星快速机动
指向、自主FXT后随观测、警报信息
快速下传

大视场，比其它设备灵敏度和空间分辨率
高1-2 数量级



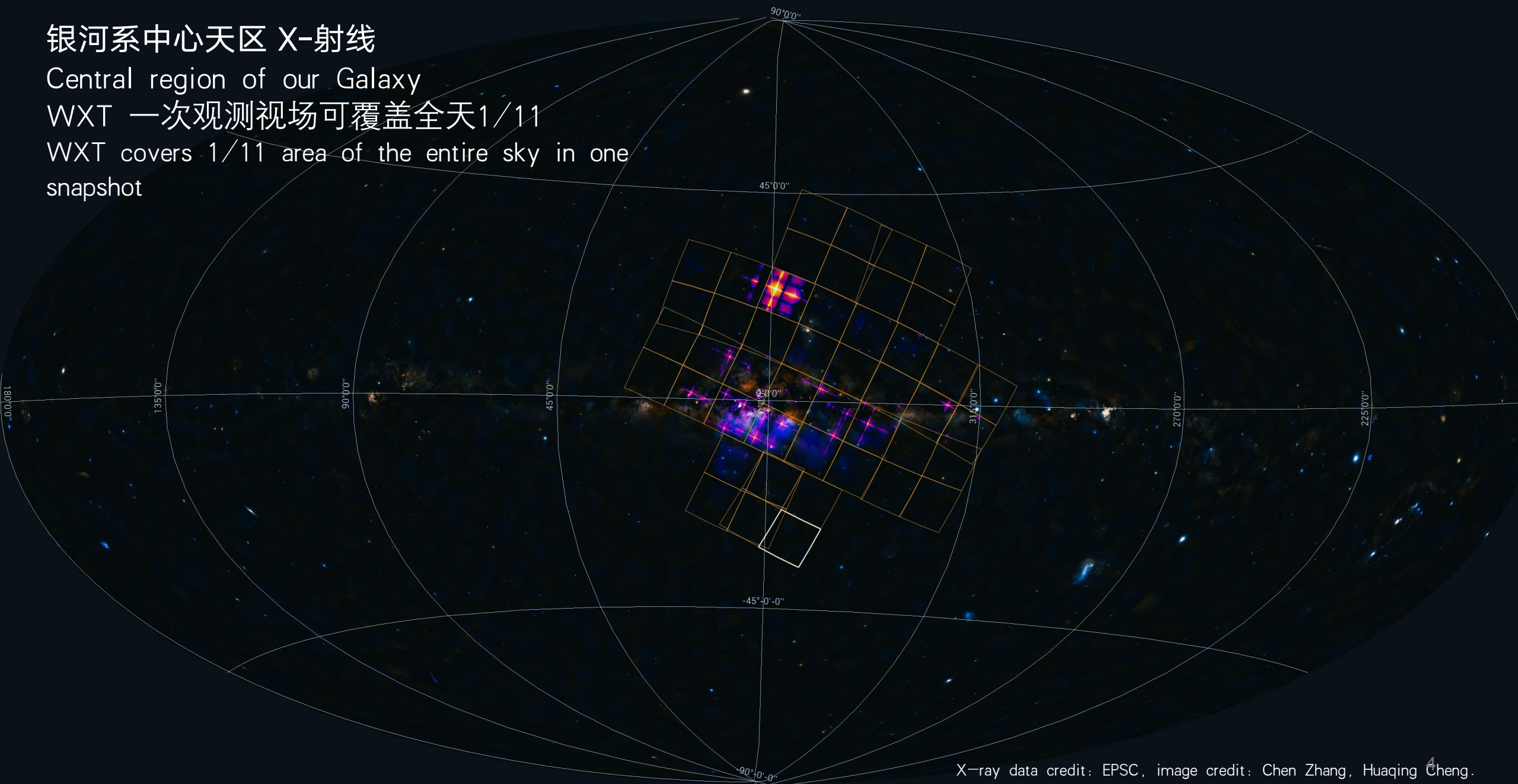
- ★ 首次大规模采用X 射线龙虾眼‘微孔聚焦成像’技术
- ★ 首次采用CMOS探测器进行空间X射线天文探测
- ★ 看得更远、更暗、更精；

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



银河系中心天区 X-射线 (紫、红、黄、蓝)

WXT 视场 3850 平方度

曝光时间4 万秒

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, Huqing Cheng.

科学载荷和卫星



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

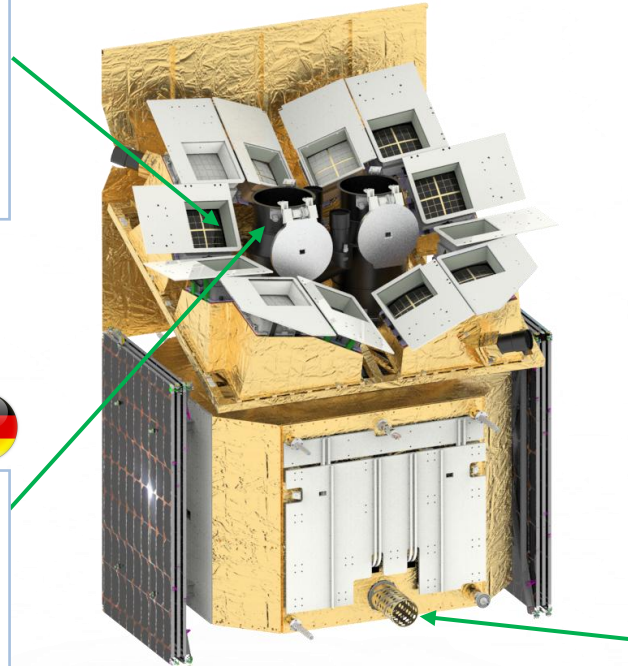


Lobster-eye MPO + CMOS
FoV: $\sim 3,600$ sq deg (1.1 sr)
Band: 0.5 – 4 keV
Resolution: $\sim 5'$ (FWHM)
Sensitivity: $\sim 1\text{mCrab}$ @1ks

Follow-up X-ray Telescope FXT (2 units)



Wolter-1 + pn-CCD (eROSITA)
FoV: 1 deg
Band: 0.5 -10keV
Resolution: 24'' (HPD, on-axis)
Effe. area: $\sim 300\text{ cm}^2$ @1keV (x 2 units)



Spacecraft



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

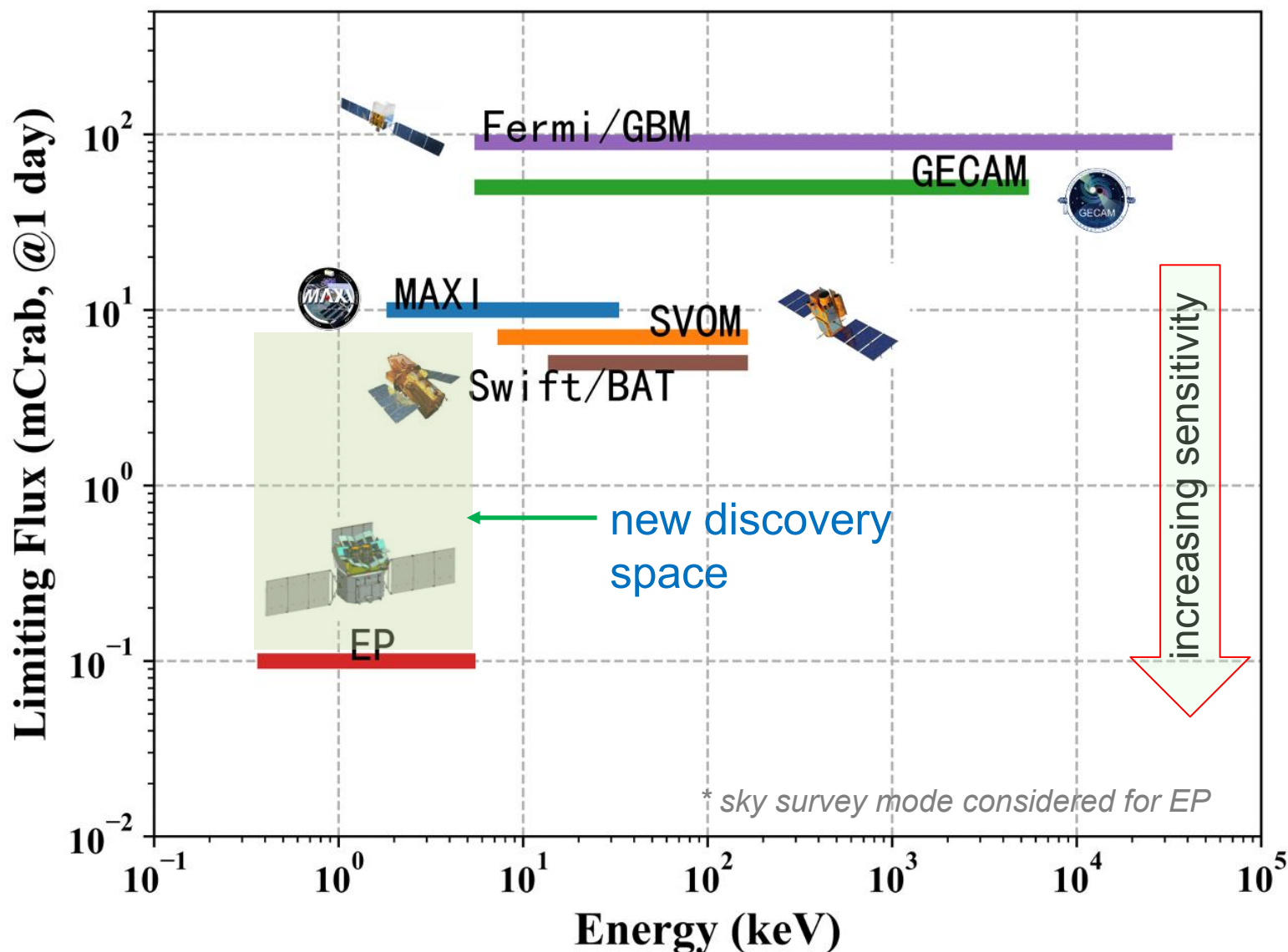
Telemetry



X/S-band (several hours)
(三亚、西澳、新加坡)
BD (down/up-link; minutes)
VHF (down-link; minutes)

WXT灵敏度和探测能段与其它宽视场高能监测设备的比较

1 天观测灵敏度

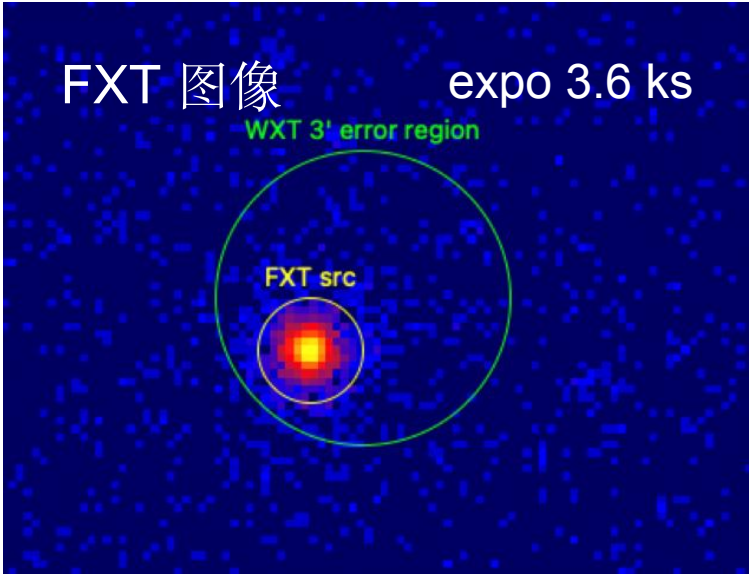


探测灵敏度比国际上高能宽视场监视器提高 1-2 数量级

快速响应： 自主后随

EP240605a

- ✦ 触发时刻 2024-06-05UT16:10:30
- ✦ 12秒后地面收到北斗警报
- ✦ 74秒后FXT开始后随观测
- ✦ FXT位置、能谱和光变表明来自恒星耀发
(2MASS J01194629-6842451)

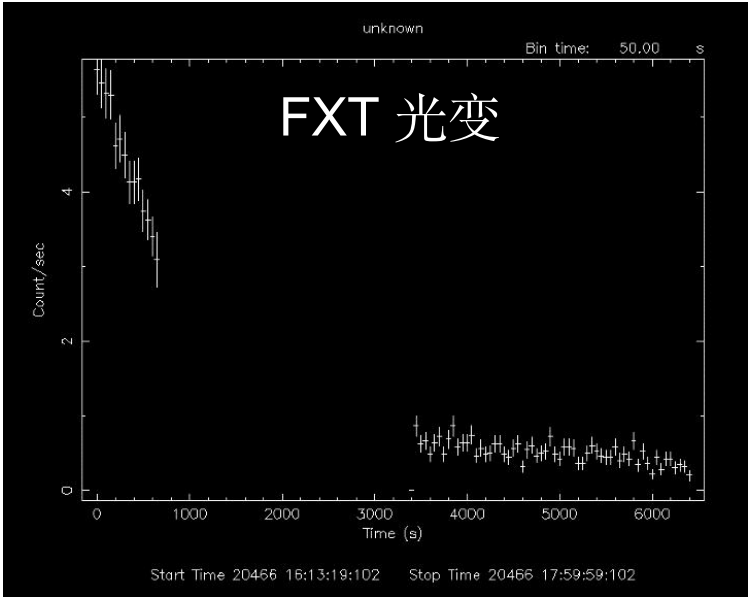


Beidou Alert: 01708918013 CMOS14

EP240605a北斗警报

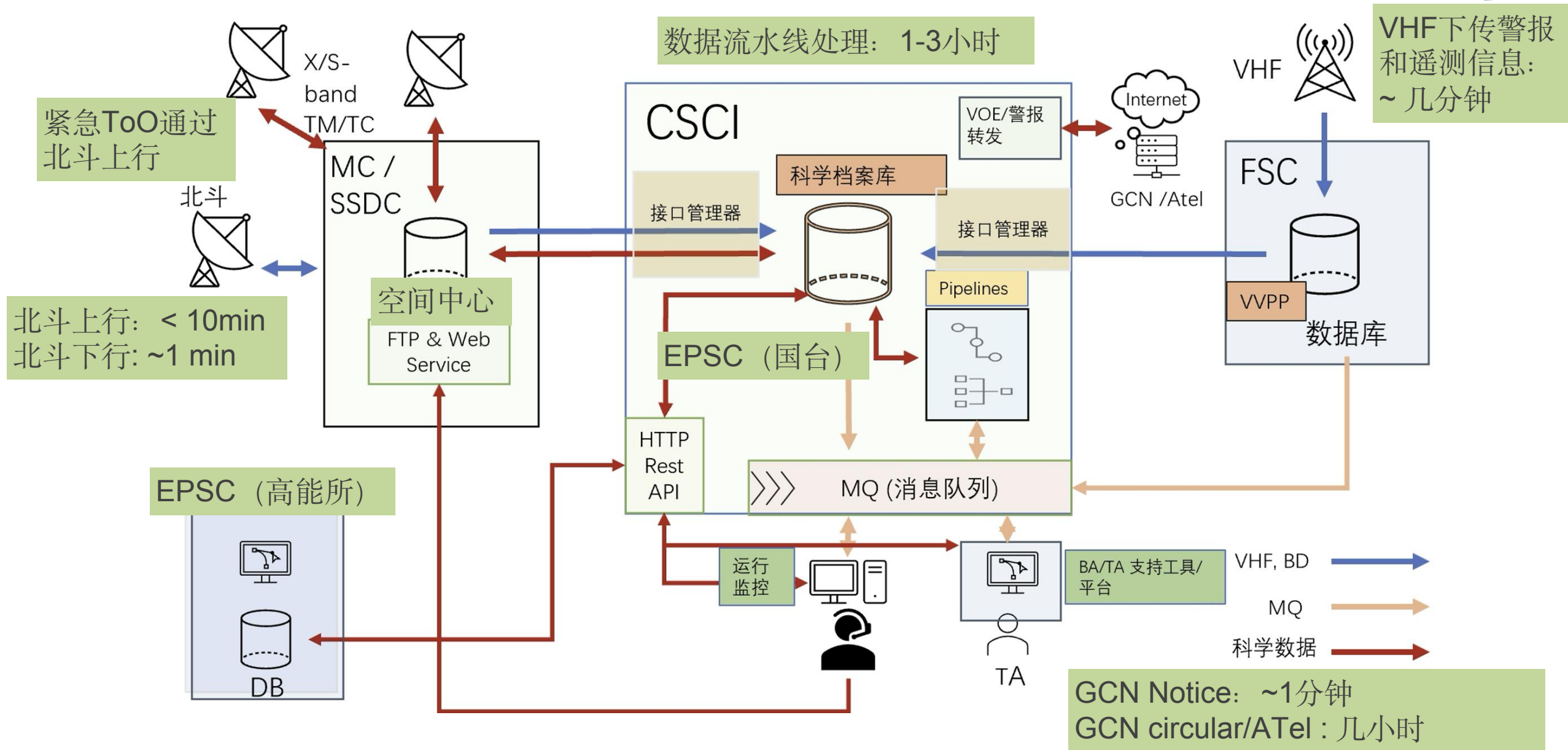
RA, Dec	19.907, -68.695
RA (HMS), Dec (DMS)	01h19m37.7s, -68d41m42.0s
Observation Time (UTC)	2024-06-05 16:00:40
X	2674.2
Net Rate	0.06
Significance	8.1

Galactic l, b	299.095, -48.223
1 σ Pos Err (arcmin)	0.692
Trigger Time (UTC)	2024-06-05 16:10:30
Y	3576.6
Variance ?	13.34
HR ?	0.18





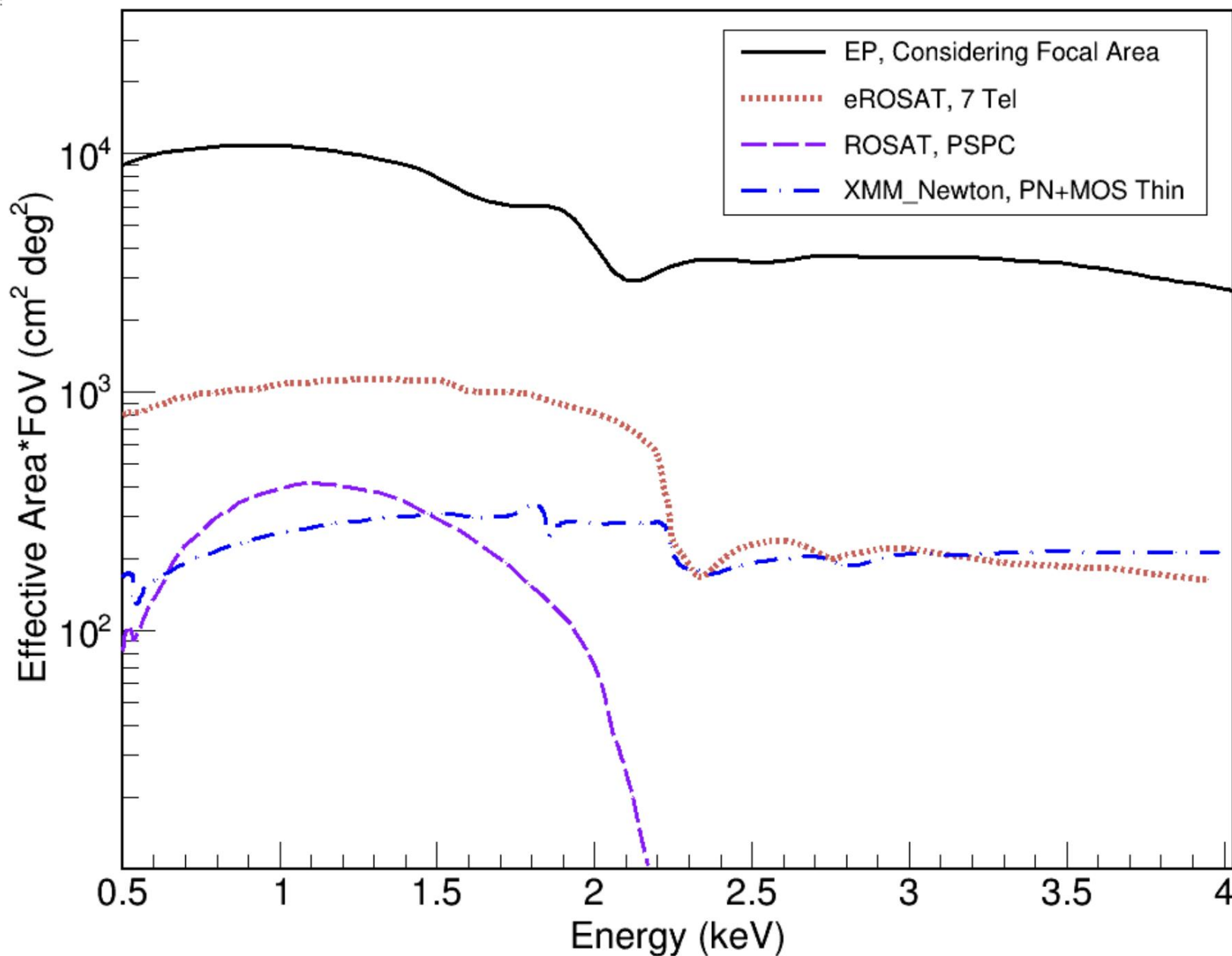
天关卫星数据流: 北斗-X/Sband-VHF



天关卫星的特点:

1. 出色的探测能力
(grasp)

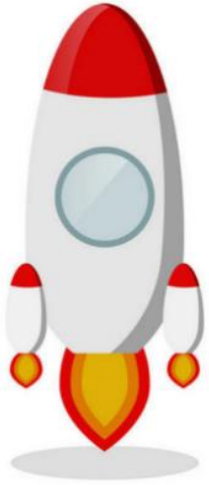
2. 快速响应





Q2: 天关卫星目前状态如何?

FIRST YEAR OF OPERATION



Spacecraft
Commissioning

Performance Verification

Nominal
Operations

Jan. 9
Launched

Jan. 11
Satellite status setting
completed

Jan. 19
WXT first light
WXT Calibration start

Apr. 5-Jul. 8
FXT continued in-orbit
calibration

Mar. 22
Performance Verification
Phase start

Feb. 22
FXT cap unfolded
FXT first light

Mar. 5-Mar. 19
FXT Calibration

Apr. 27

Jul. 9

Jul. 22

EP consortium formally released the first
light images acquired in orbit

Nominal Operations Start

Satellite Delivery Review

Nominal Operations (3ys)



2024-1-9 天关卫星在西昌成功发射

6 年：自任务立项

11 年：自任务概念提出

13 年：自开展国台 XIL 技术研发



LM-2C @ 西昌



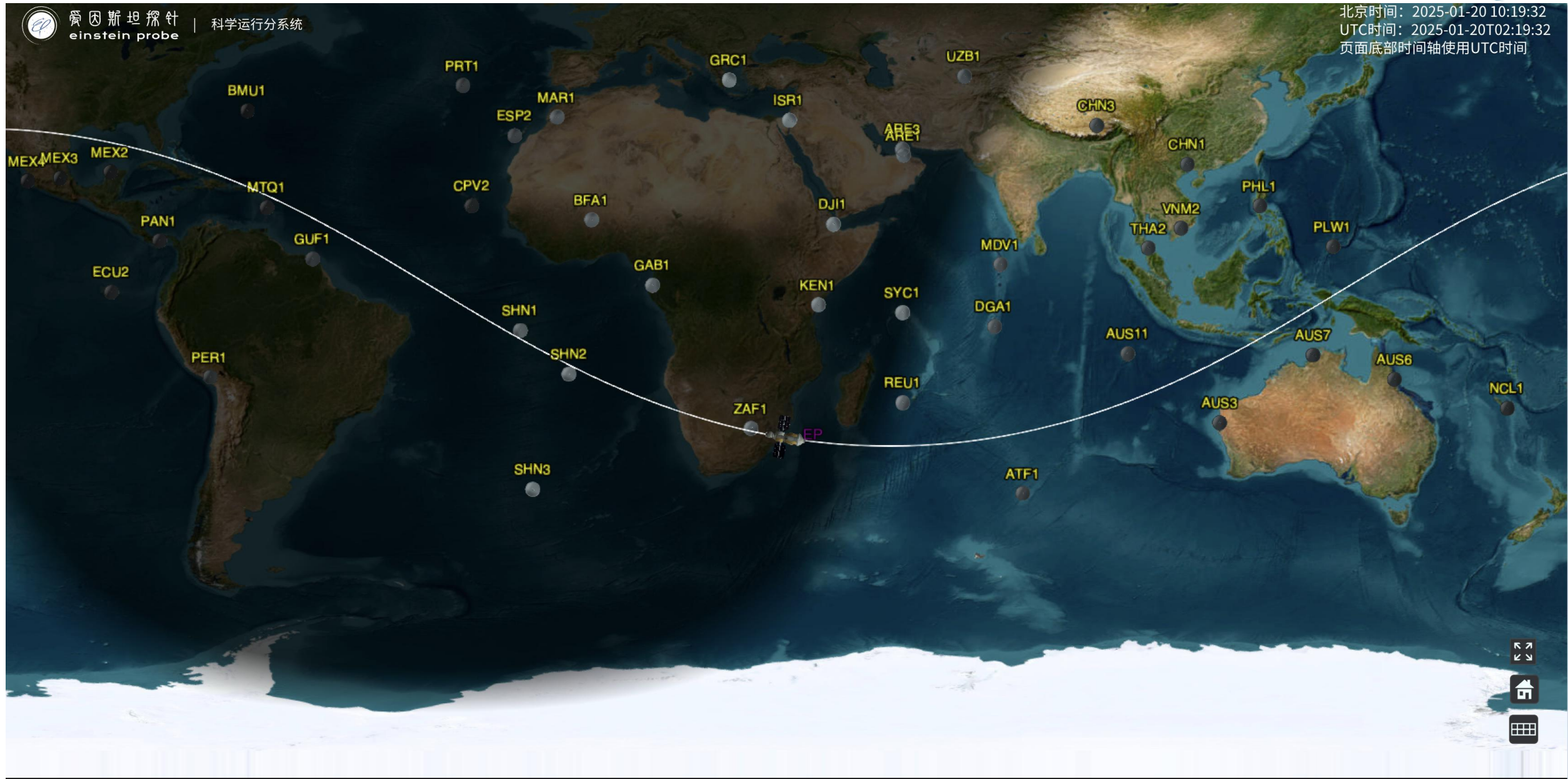
龙年大吉

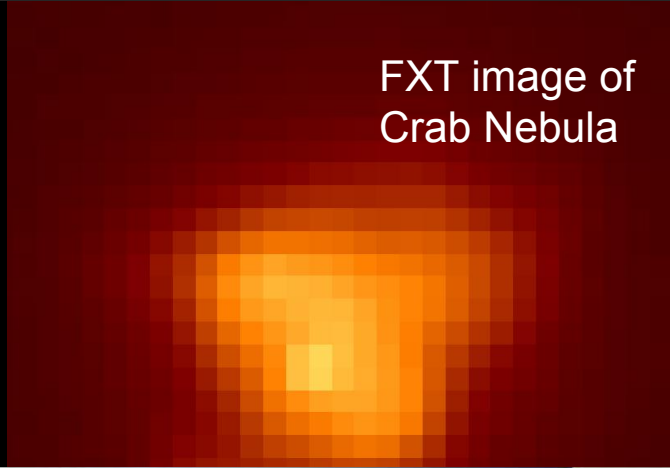
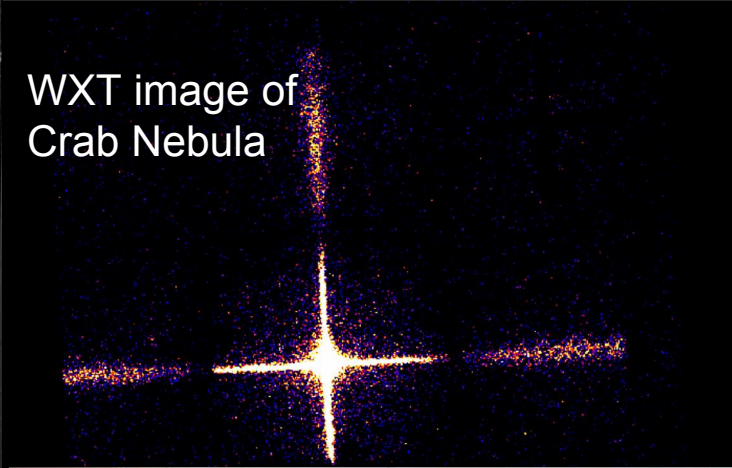
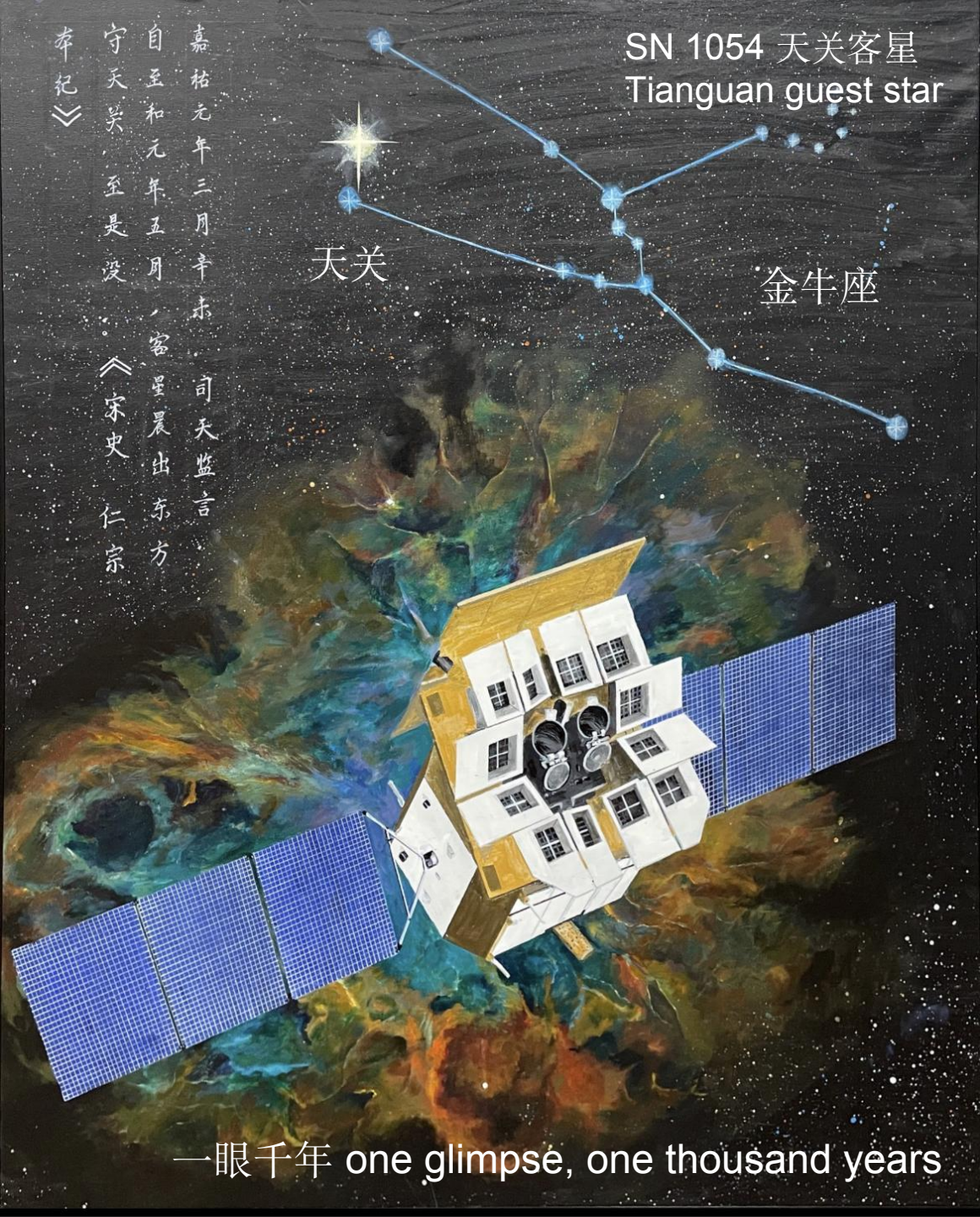
天关卫星轨道



爱因斯坦探针 | 科学运行分系统
einstein probe

北京时间: 2025-01-20 10:19:32
UTC时间: 2025-01-20T02:19:32
页面底部时间轴使用UTC时间





Cycle-1 observations

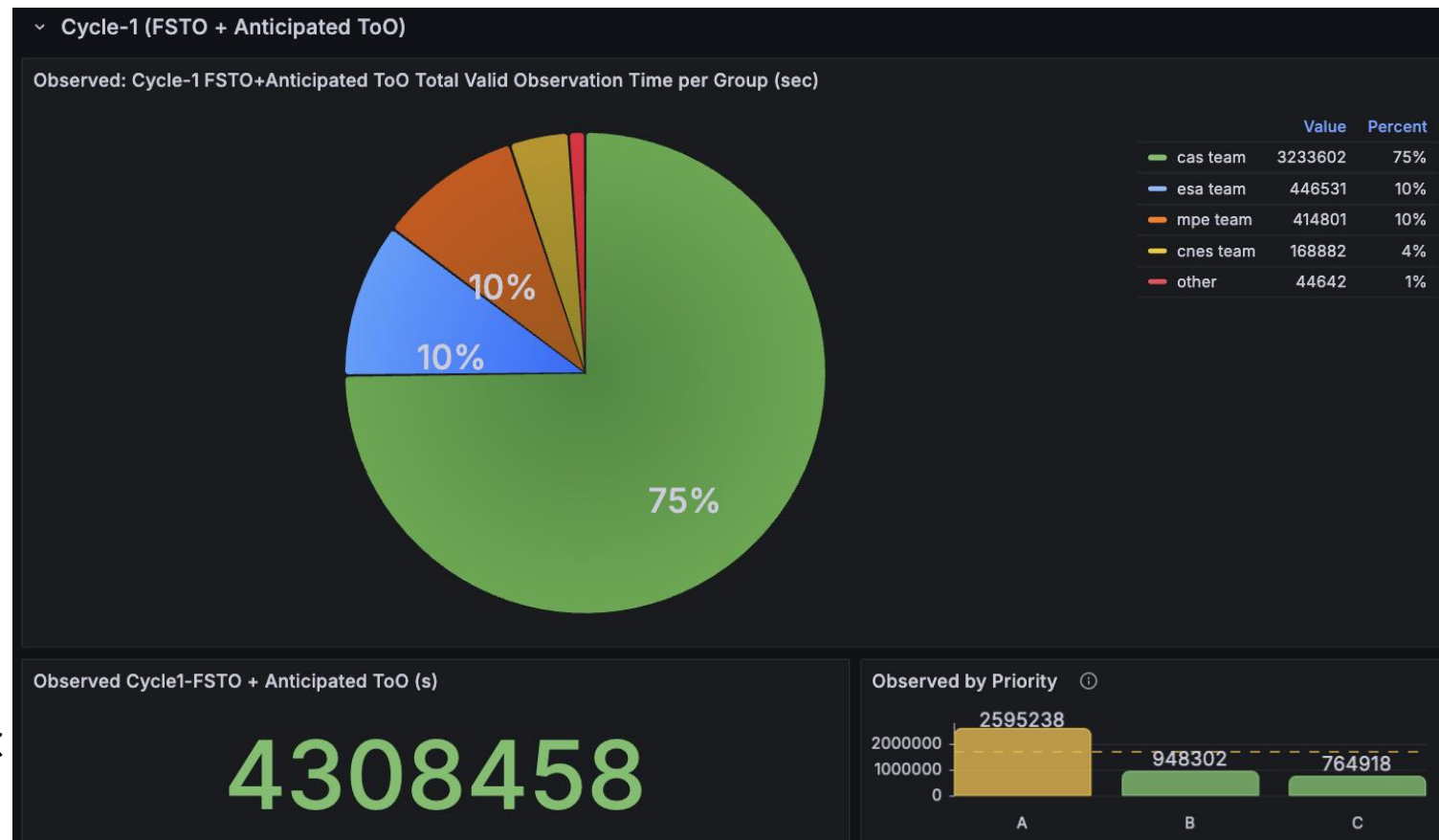


□ Cycle1 targets (FSTO):

- ✓ Number of Proposals : 68
- ✓ Number of sources : 699
- ✓ Requested time: 6.2×10^6 s

□ Observed Cycle1:

- ✓ Observation Time : 2024.7.9 ~now
- ✓ Number of sources: ~600
- ✓ Total observed exposure time: 4.3×10^6 s



ToO observations



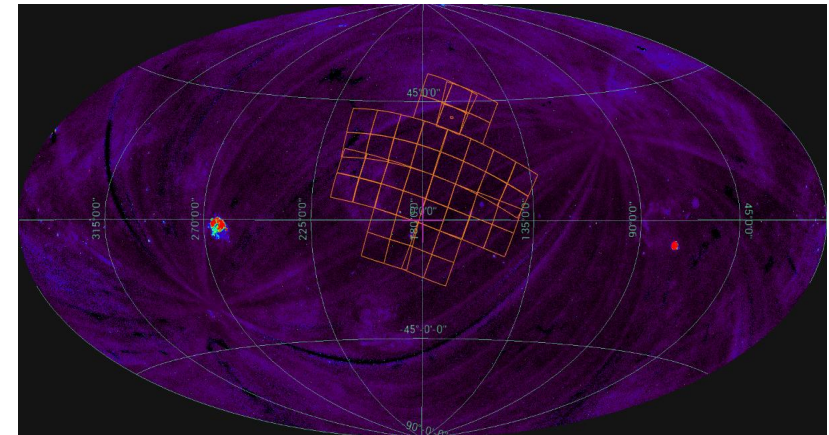
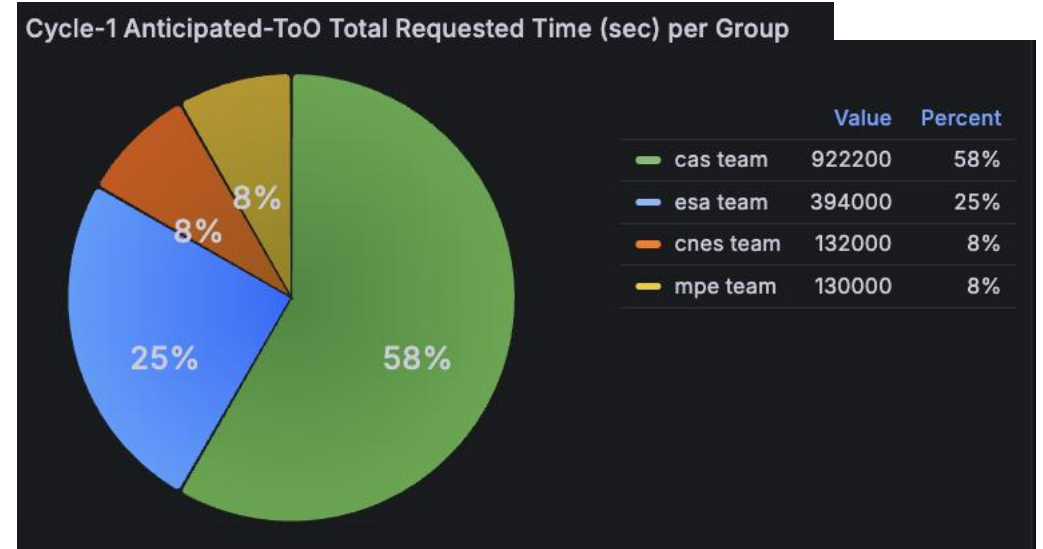
□ ToO (targets of opportunity):

- ✓ Observation Time: 2024.7.9 ~ up to now
- ✓ Number of observations: 1012
- ✓ Observed exposure time: 4.4×10^6 s

□ Cycle-1 Anticipated-ToO:

- ✓ Number of proposals: 29
- ✓ Number of sources: 535

□ EP ToO: evaluated by EP Time Allocation Committee (TAC)



ToO example

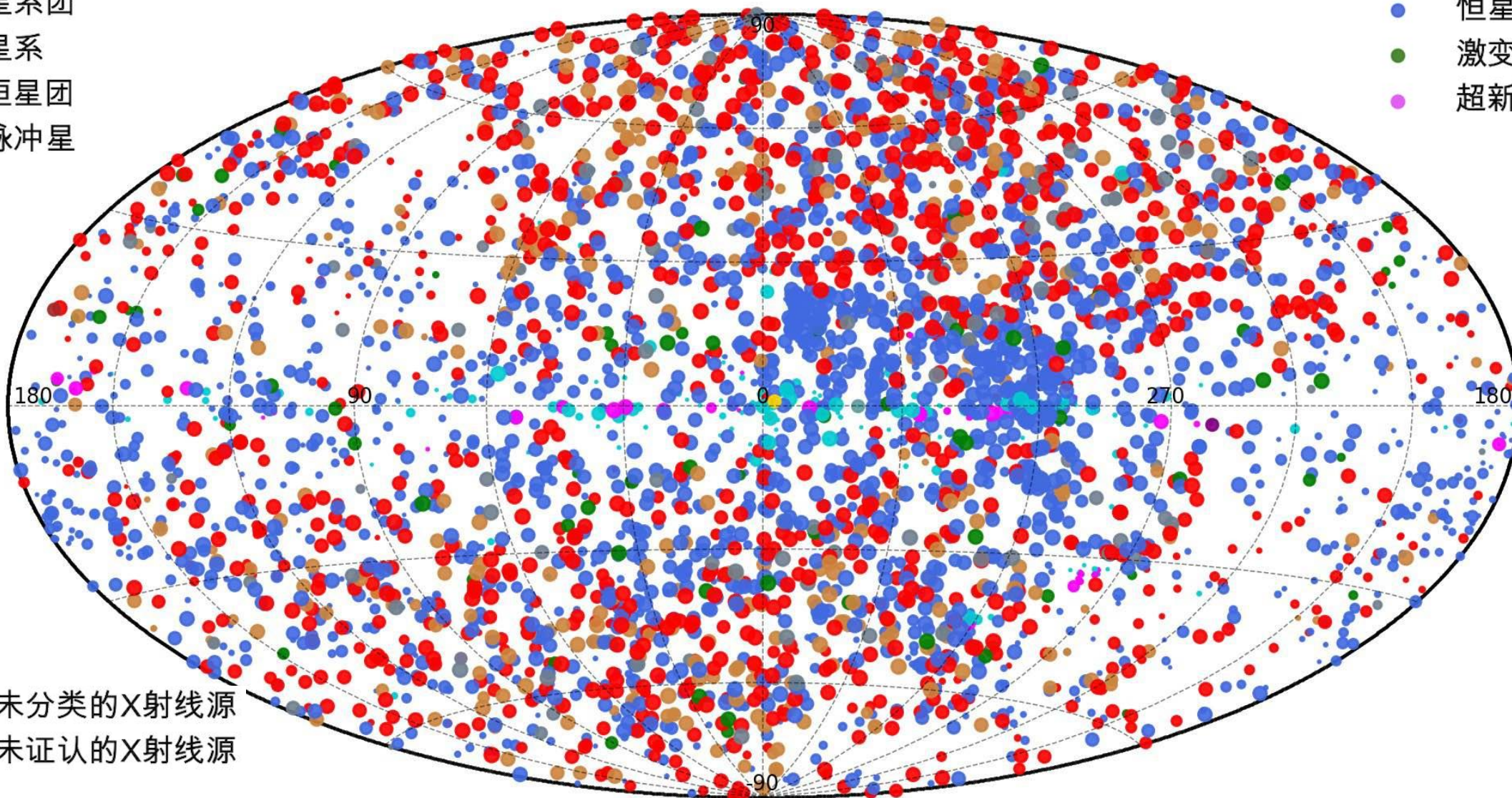
EP-WXT 探测到的 X 射线源（亮源）

已知源 6000+; 暂现源100+; 恒星耀发1000+

- X射线双星
- 星系团
- 星系
- 恒星团
- 脉冲星

- 活动星系核
- 恒星
- 激变变星
- 超新星遗迹

- 未分类的X射线源
- 未认证的X射线源





Q3: 天关卫星观测模式是怎样的？

EP观测模式

- * 轨道

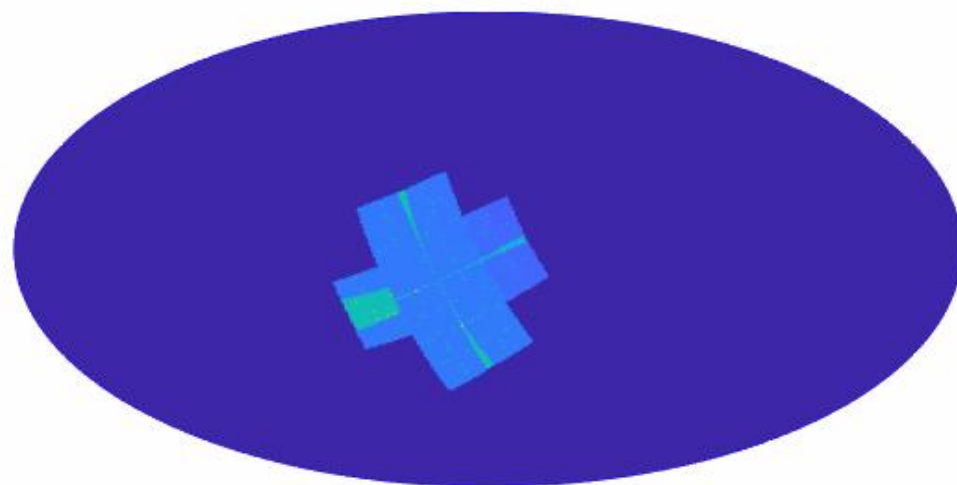
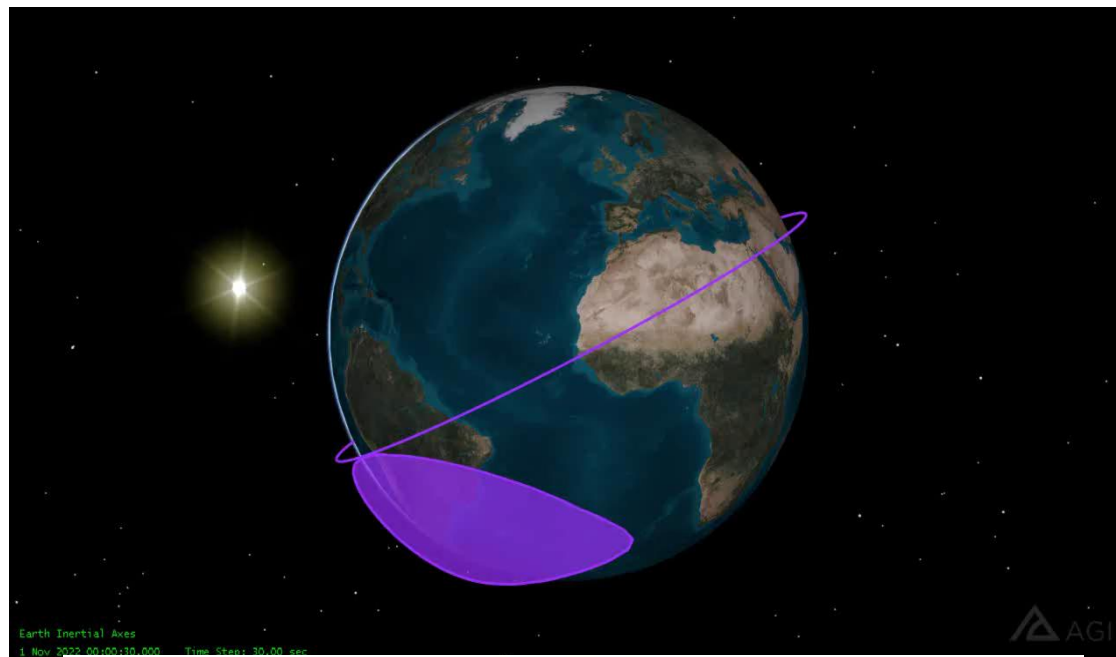
- ★ 高度592 km, 轨道周期 96min
- ★ 轨道倾角 29 deg.

- * 观测模式

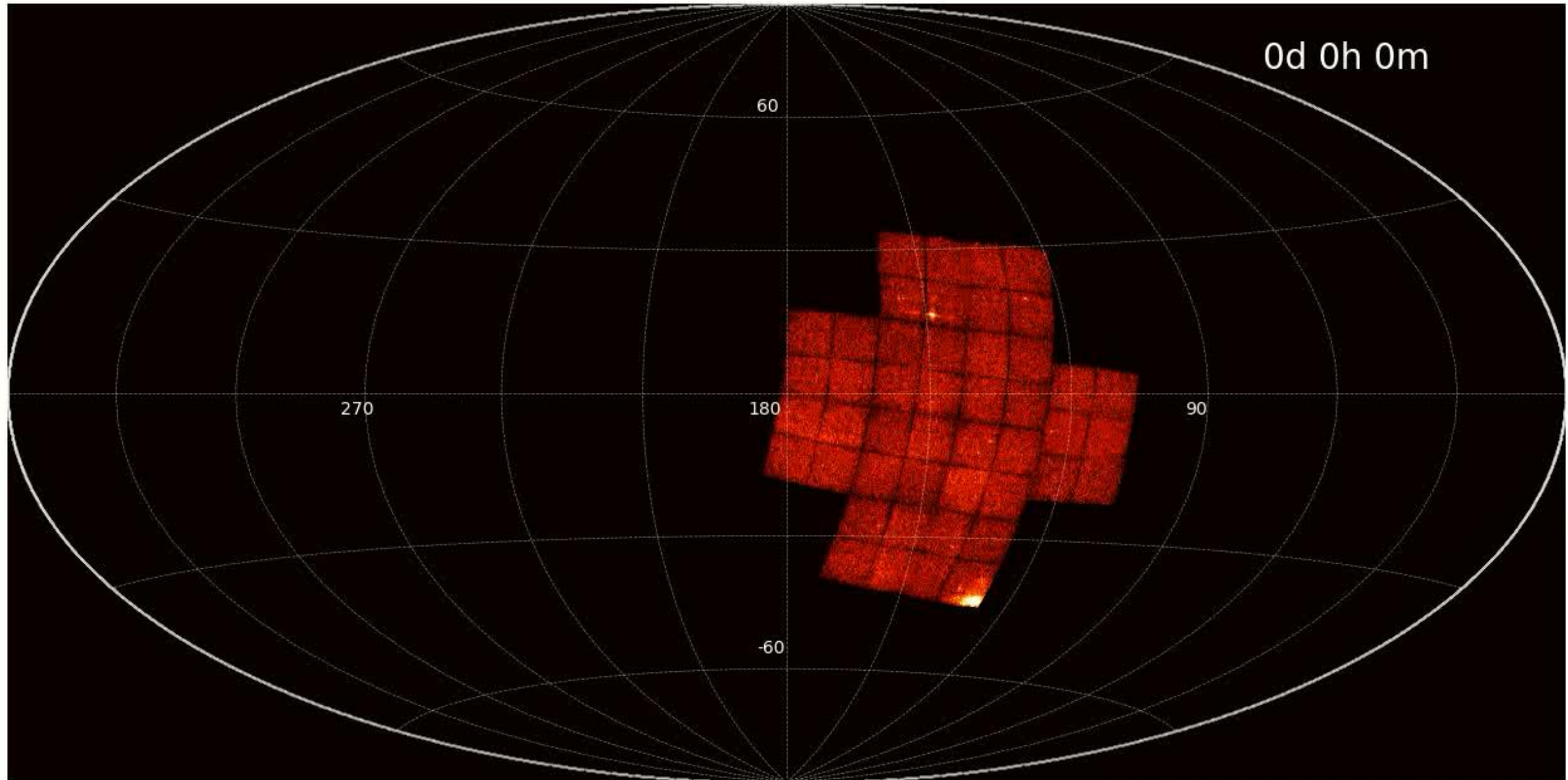
- ★ 巡天模式 (**primary WXT**)
- ★ 自主后随模式 (**FXT**)
- ★ **ToO** 模式 (**FXT, WXT**)
- ★ 定标模式

- * 巡天模式

- ★ 指向夜天区
- ★ 每轨**3**个指向, 每个指向 **~20min**
- ★ **3**轨覆盖夜天区 (约**5**个小时)
- ★ 半年覆盖全天
- ★ 指向由**FXT**决定, **FXT**指向预先选定目标



EP-WXT巡天观测@1天



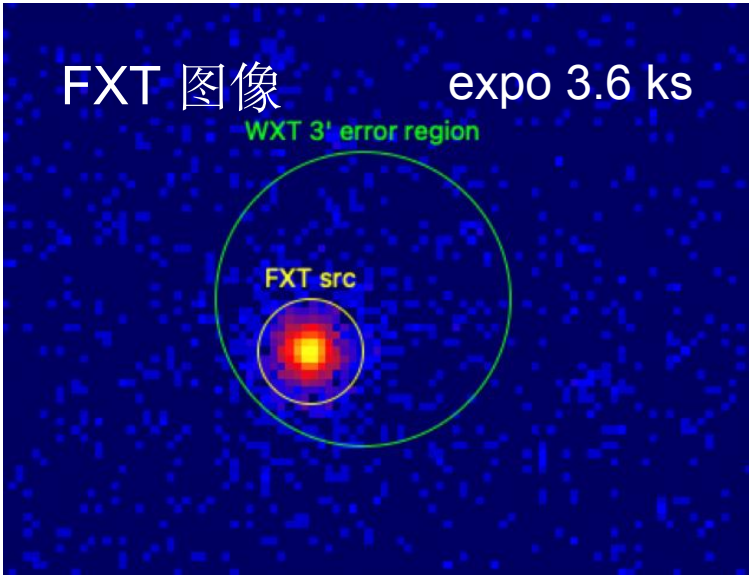
自主后随模式

触发条件

- * 信噪比 > 7
- * 银纬大于10度 ($|b| > 10 \text{ deg}$)
- * 不在星上源表的白名单中
- * 满足观测约束
- * 优先级高于星上当前执行任务

示例：EP240605a

- * 触发时刻 2024-06-05UT16:10:30
- * 12秒后地面收到北斗警报
- * 74秒后FXT开始后随观测
- * FXT能谱和光变表明来自恒星耀发

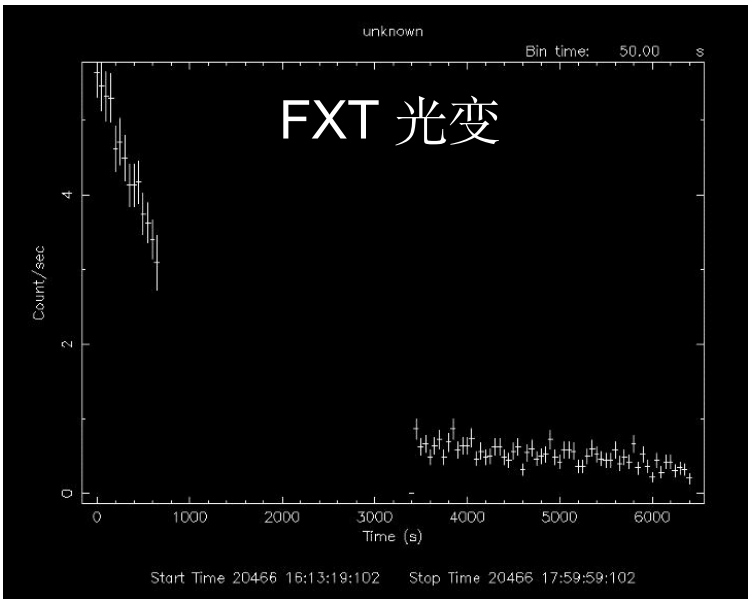


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EP240605a北斗警报

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RA (HMS), Dec (DMS)	01h19m37.7s, -68d41m42.0s
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Significance	8.1

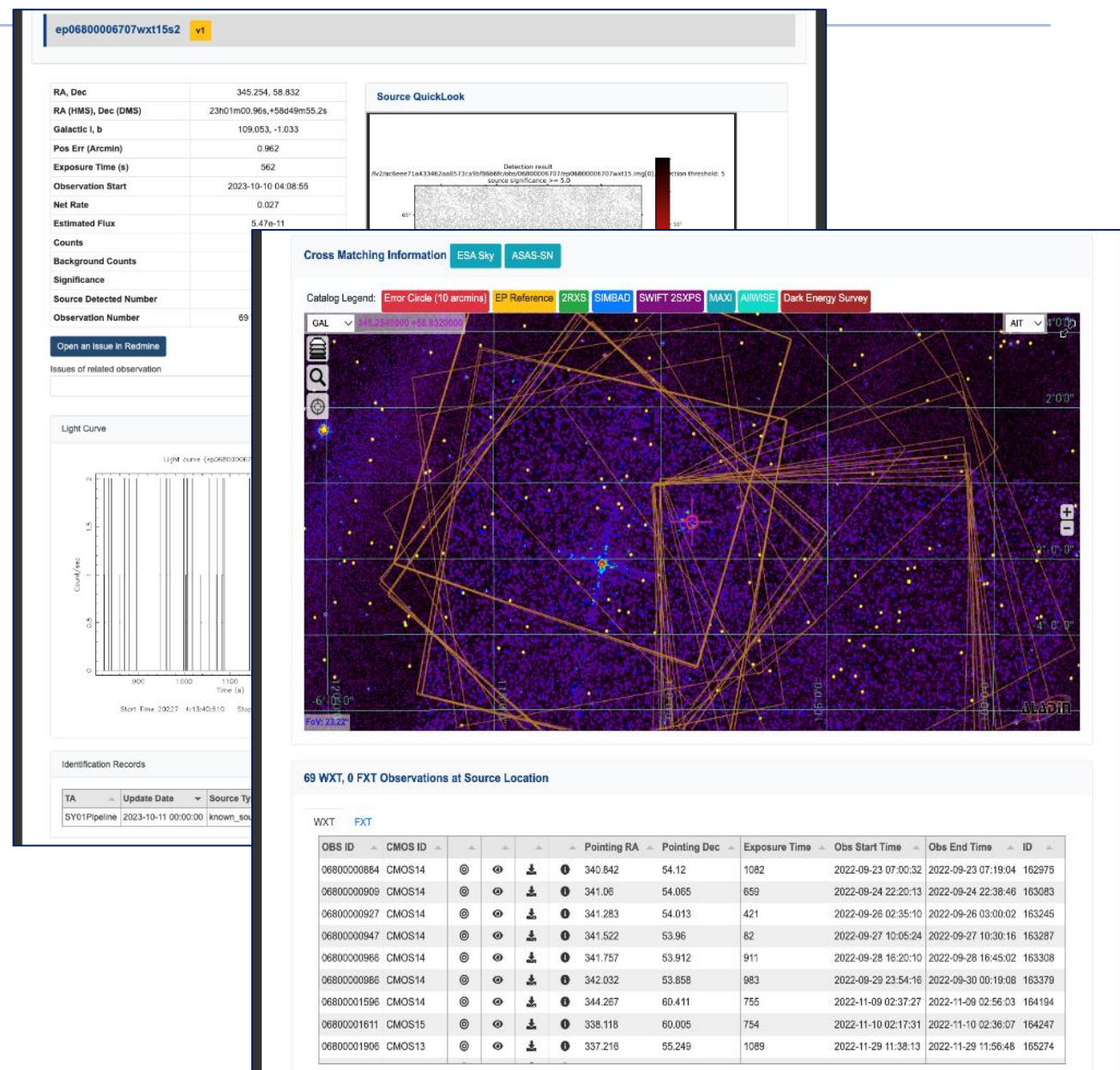
Galactic l, b	299.095, -48.223
1 σ Pos Err (arcmin)	0.692
Trigger Time (UTC)	2024-06-05 16:10:30
Y	3576.6
Variance ?	13.34
HR ?	0.18



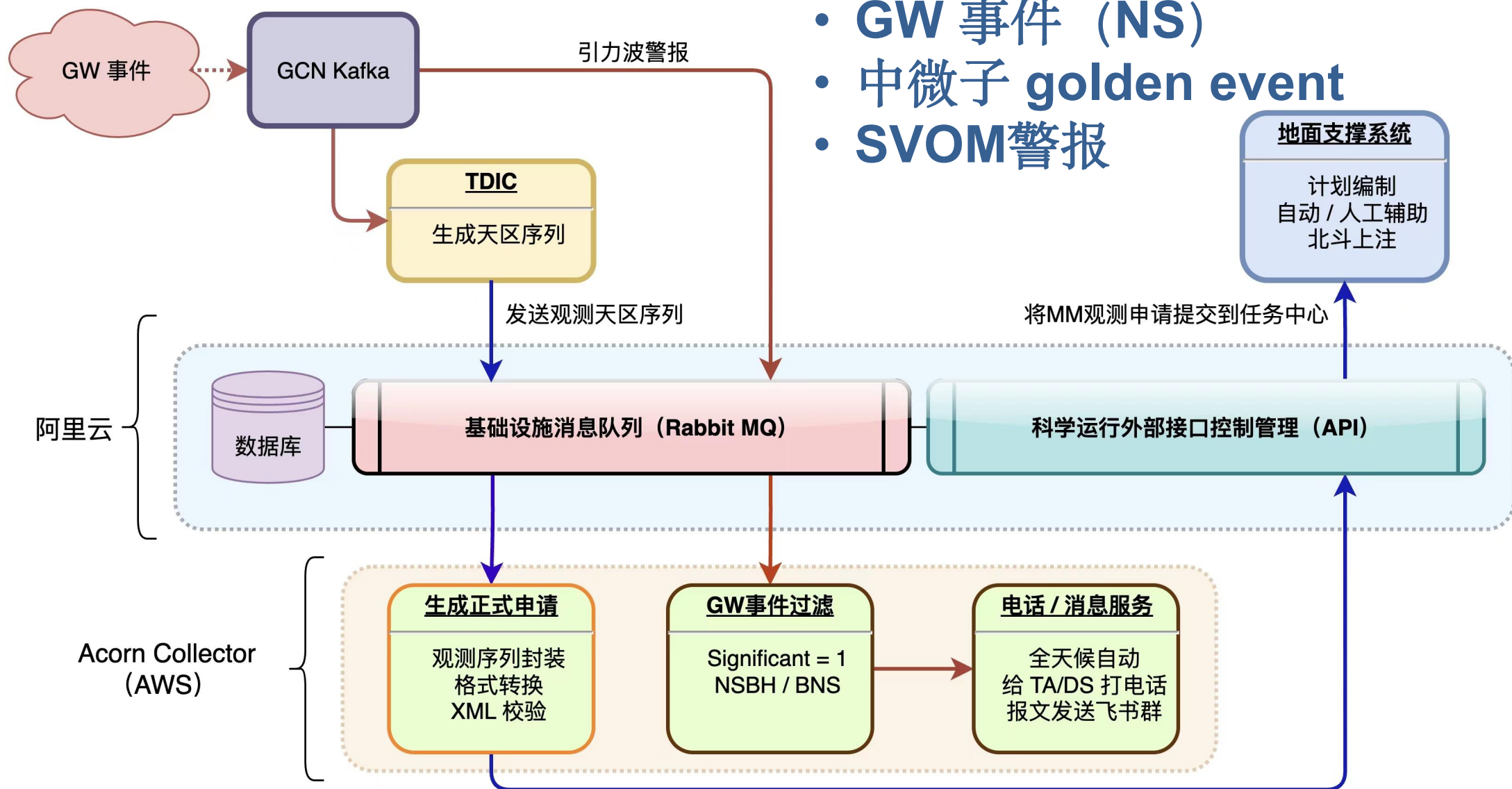
ToO 观测模式 I: 地面触发警报

自动化证认+人工证认

- ★ 已知源表匹配
- ★ 机器学习分类(去除宇宙线)
- ★ 自动关联Atel GCN TNS警报
- ★ 人工结合多波段数据



ToO 观测模式 II: 外部警报 (多波段 & 多信使)



科学用户 ToO

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EP Observing Proposal System (EOPS)

EP Observing Proposal Cycle-2: STP Observer Program

[Cycle-2 Proposer's Guidance](#)

STP Observer Program, including non-ToO observations and anticipated-ToO for known sources, opens to STP Member and Associate Member only. Please read the proposer's guidance carefully before submitting a proposal.

[Create a new proposal](#)[My proposal list](#)

EP Observing Proposal Cycle-2: Guest Observer (GO) Program

[Cycle-2 Proposer's Guidance](#)

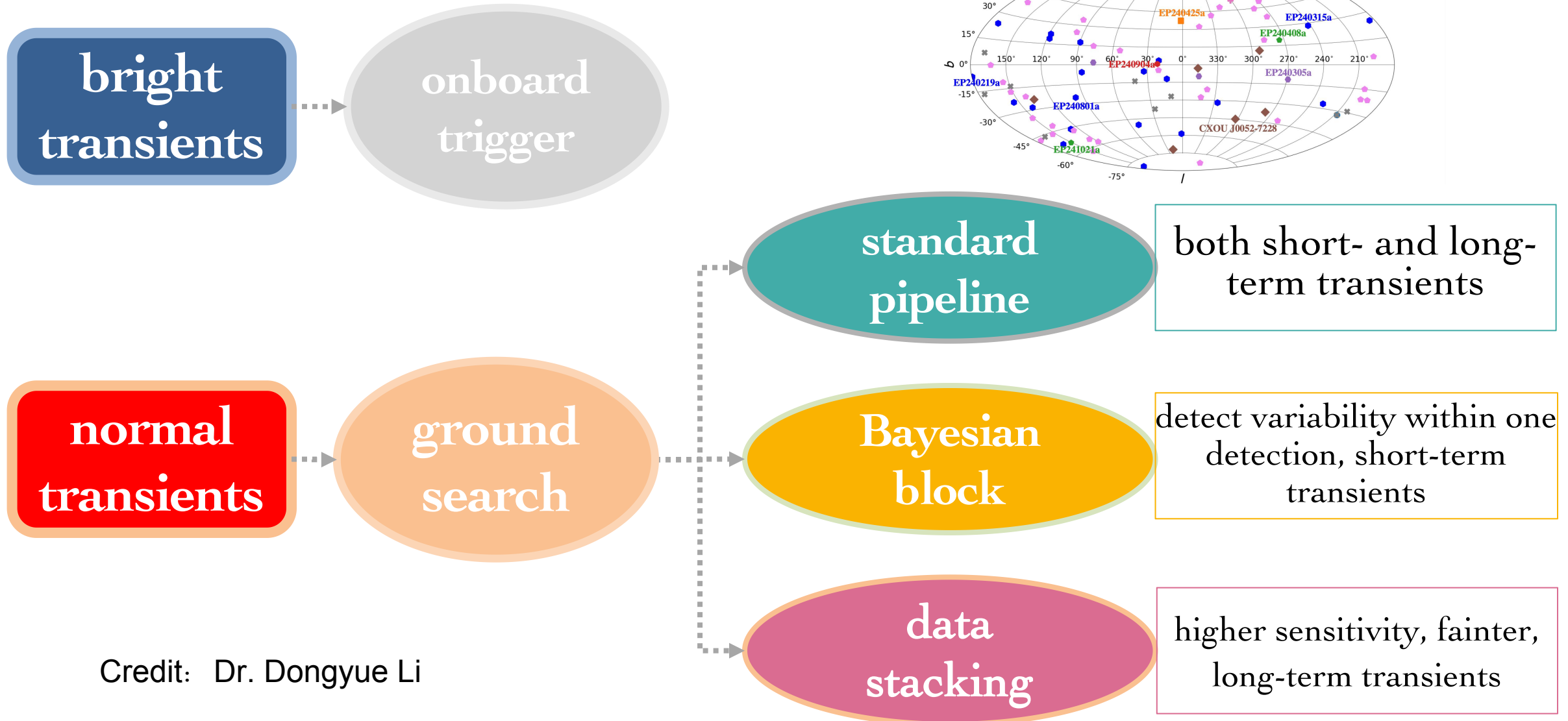
Guest Observer (GO) Program, including non-ToO observations and anticipated-ToO for known sources, opens to non-STP proposers whose primary affiliations are in China. Please read the proposer's guidance carefully before submitting a proposal.

[New ToO Observation](#)[My proposal list](#)[ToO Proposer's Guidance](#)



Q4: 我们是如何通过天关卫星发现暂现源的?

EP-WXT transient search



Credit: Dr. Dongyue Li

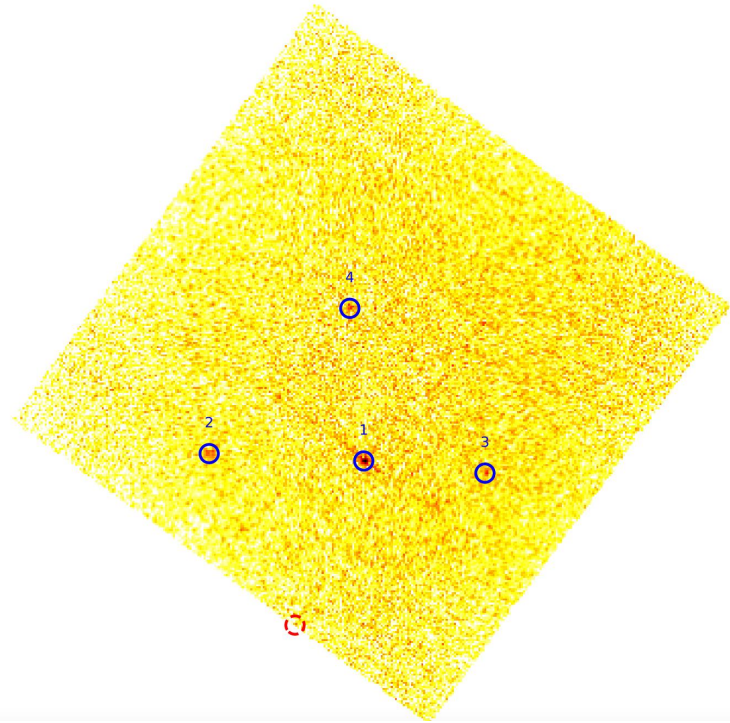
Daily Scientific Data Analysis



source detection

Matching with
Known Source Lists

Categorization



known source lists:
WXT known source list

EP reference catalog:
RASS, eROSITA, 2sxps, 4XMM,
Chandra.....

if there is no-match:
transient & burst

Source ID	Obs Time (UTC)	Type	Tags	Category
		All		
ep11908876121wxt8s1	2024-11-26 02:01:25	source	known_source	Star
ep11908876121wxt9s2	2024-11-26 02:01:25	source	known_source	AGN
ep11908876121wxt42s1	2024-11-26 02:01:25	source	known_source	AGN
ep11908876121wxt10s2	2024-11-26 02:01:25	source	known_source	Star
ep11908876121wxt24s1	2024-11-26 02:01:25	source	known_source	AGN
ep11908876121wxt40s1	2024-11-26 02:01:25	source	known_source	Unverified
ep11908876121wxt39s3	2024-11-26 02:01:25	no_match		
ep11908876121wxt45s1	2024-11-26 02:01:25	source	known_source	AGN
ep11908876121wxt5s1	2024-11-26 02:01:25	source	known_source	Cluster of Galaxies
ep11908876121wxt9s1	2024-11-26 02:01:25	source	known_source,stellar_flare	Star
ep11908876121wxt43s1	2024-11-26 02:01:25	source	known_source	AGN
ep11908876121wxt48s1	2024-11-26 02:01:25	source	known_source	XRB
ep11908876121wxt19s1	2024-11-26 02:01:25	cosmic_ray		
ep11908876121wxt34s1	2024-11-26 02:01:25	source	known_source	XRB
ep11908876121wxt39s2	2024-11-26 02:01:25	source	known_source	Galaxy
ep11908876121wxt37s1	2024-11-26 02:01:25	source	known_source	Cluster of Galaxies
ep11908876121wxt18s1	2024-11-26 02:01:25	source	known_source	CV
ep11908876121wxt14s1	2024-11-26 02:01:25	source	known_source	AGN

- Known Sources
- Transient Sources
- Burst Sources
- Stellar flares

Daily Data Processing Summary

- **Data Transmission:** ~10 orbits/day with hour-level delay
- **Automated Analysis:** data pipeline, hour-level
- **Detection Capacity:** 500–600 sources/day, including ~dozens of ‘transient’ sources

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

Data products: source detection page



ep11900234369wxt1s1

v1

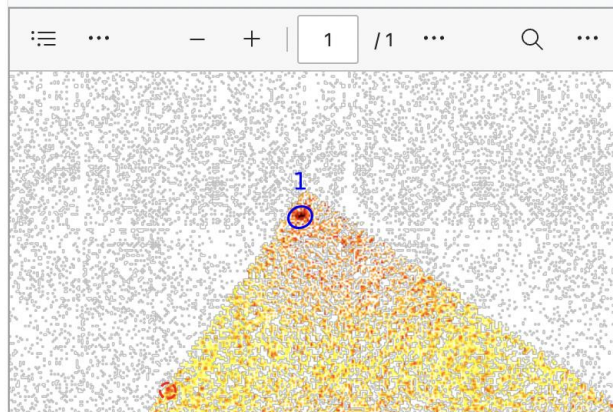
X-Band

RA, Dec	171.127, -59.28
RA (HMS), Dec (DMS)	11h24m30.4s, -59d16m47.2s
Galactic l, b	292.023, 1.738
90% Pos Err (arcmin)	2.311
Exposure Time (s)	1372
Observation Start (UTC)	2025-05-19 09:25:50
Net Rate	0.053245984
Estimated Flux (erg/cm^2/s)	1.06e-10
Counts	73.05349
Background Counts	0.66497463
Significance	12.459656
Source Detected Number	27 WXT, 0 FXT
Observation Number	727 WXT, 0 FXT

[Open an issue in Redmine](#)

Issues of related observation

Source QuickLook



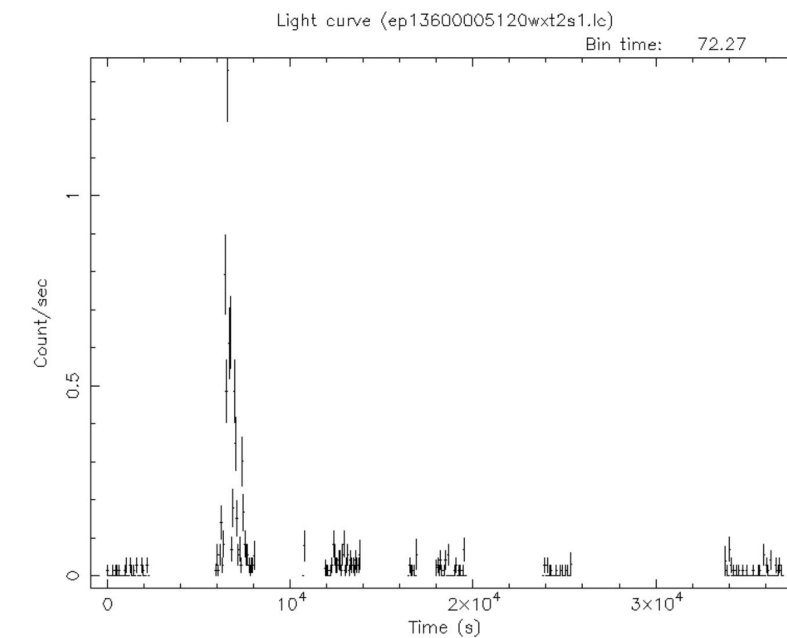
[Show image in DS9](#)

[Download level1 data](#)

[Download Level2-3 Data](#)

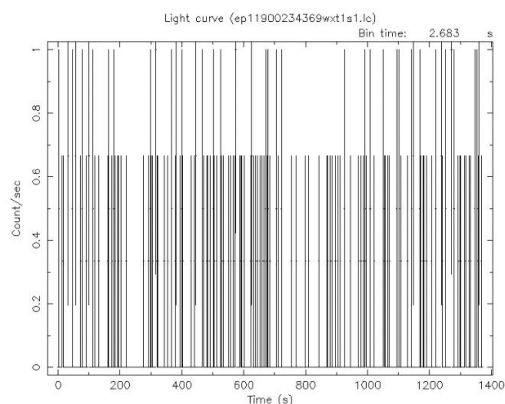
Fast X-ray transient

Light Curve



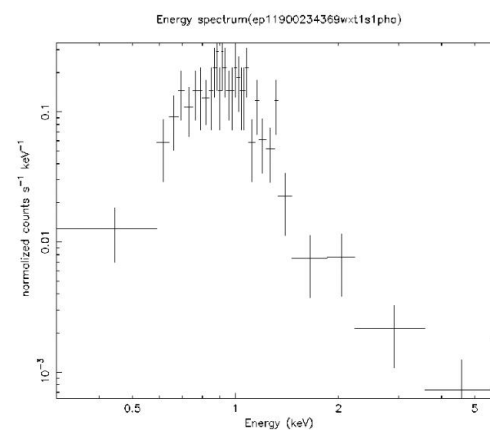
Start Time 20384 18:29:03:475 Stop Time 20385 4:44:32:311

Light Curve



Start Time 20814 9:27:01:425 Stop Time 20814 9:49:52:252

Spectrum

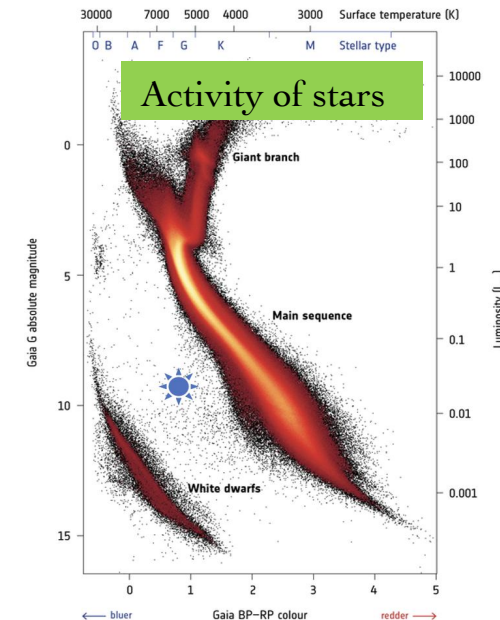
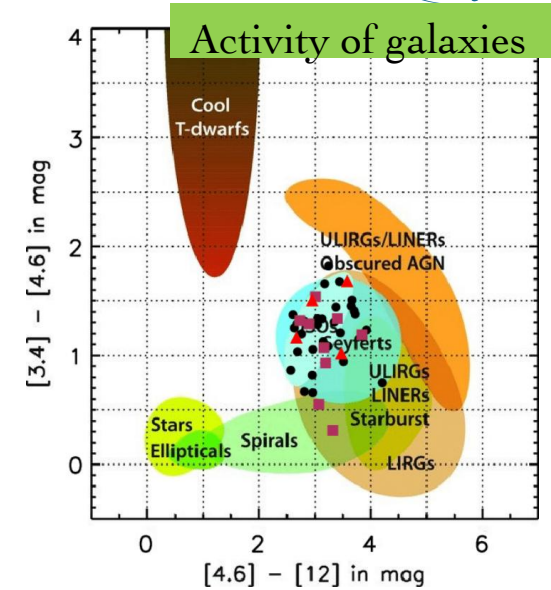
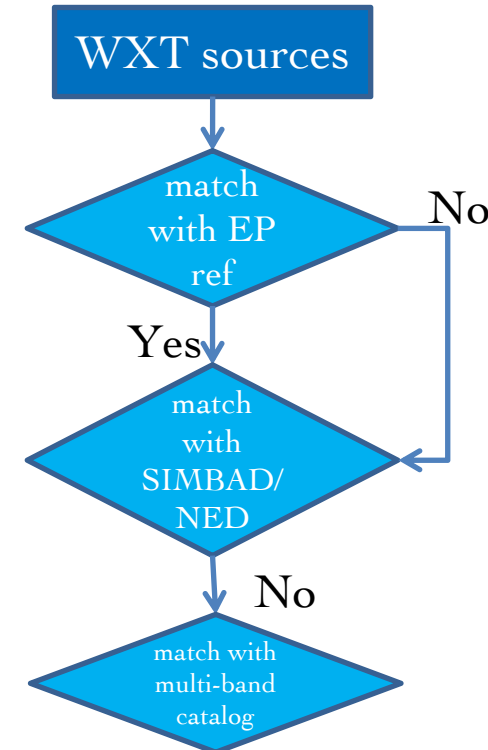
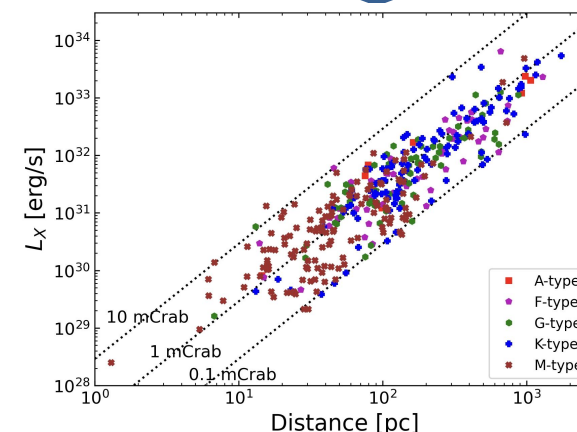
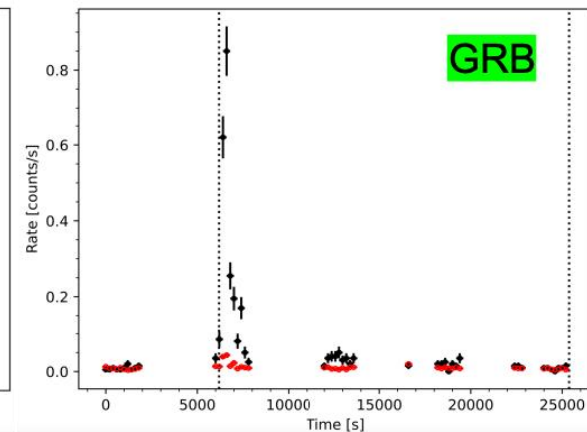
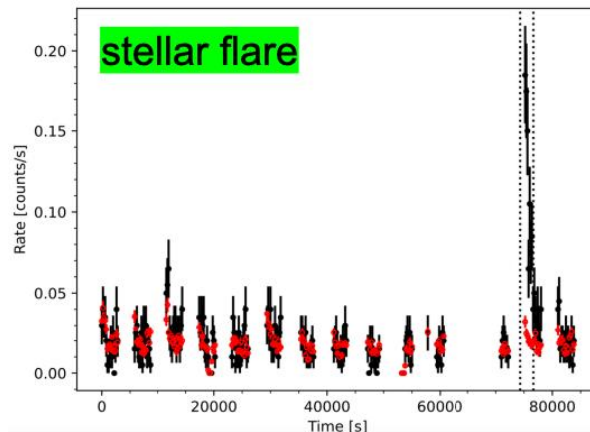
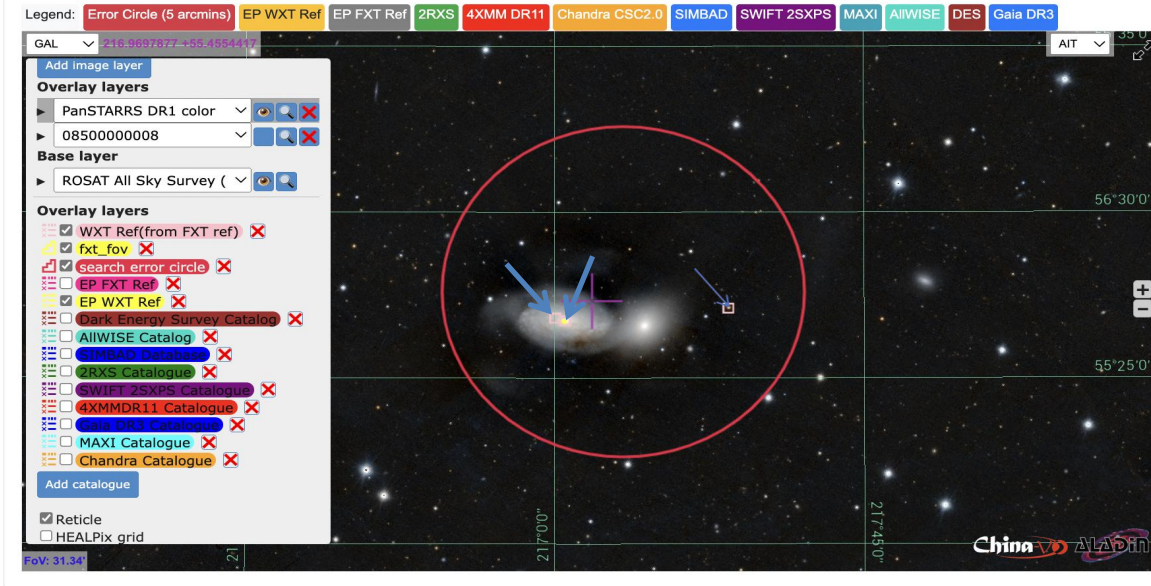


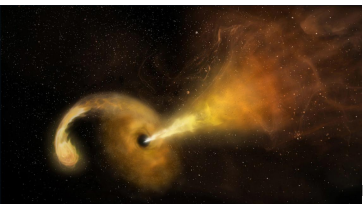
Multiwavelength identification



X-ray Counterpart from EP Reference Catalog

	Name	RA	Dec	Pos Err	Sep	Flux	Prob	P_single	ID
1	2RXS J102331.3+195140	155.881	19.861	4.896	121.651	7.475e-12	9.533e-1	3.309e-1	9310185
2	1eRASS J102330.6+195153	155.878	19.865	1.883	109.518	3.176e-11	1.000e+0	4.281e-1	8197699
3	2SXPS J102325.8+195616	155.858	19.938	4.000	176.095	8.371e-11	4.670e-2	2.366e-2	8223180



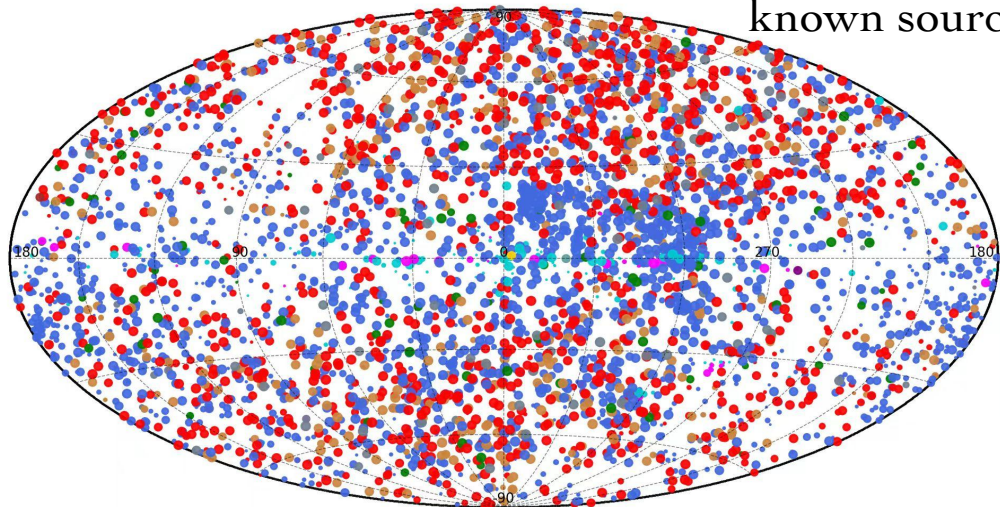


Data products: catalog & source page

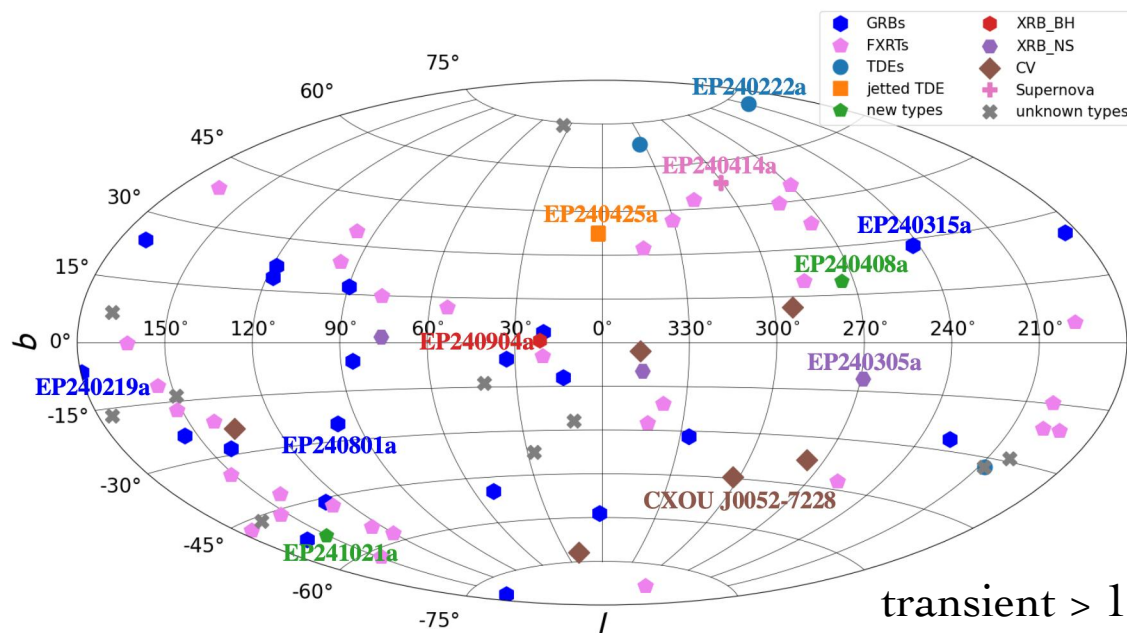


Galactic coordinate

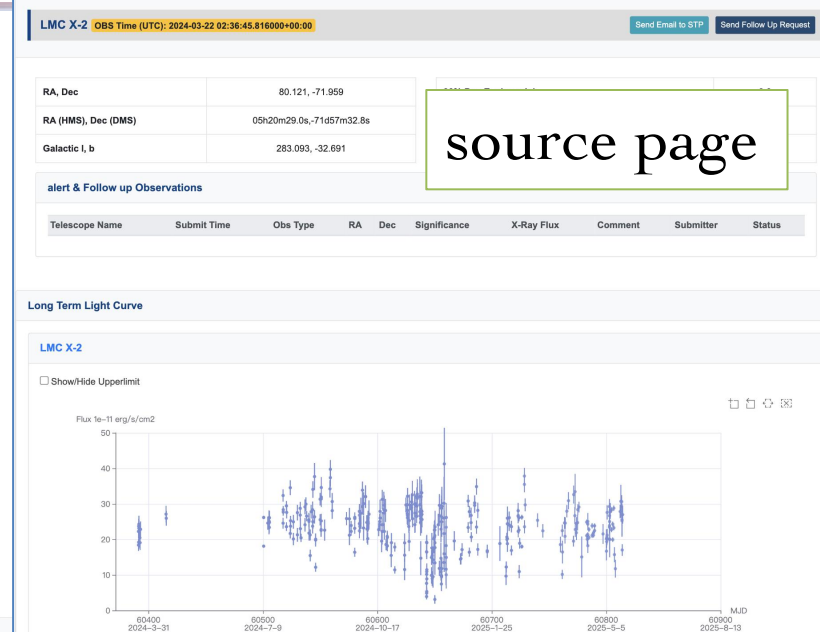
known source > 6000



- AGN
- Star
- CV
- SNR
- XRB
- Galaxy Cluster
- Galaxy
- Star Cluster
- Pulsar
- Unclassified
- Unverified

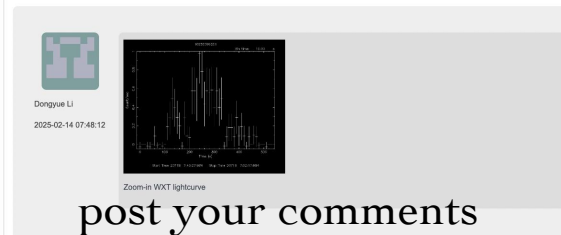


transient > 100



source page

Comments for the source



post your comments
for the source

Detection of the X-ray source associated with SDSS J133519.91+072807.4 by Einstein Probe

alert_from	ATel
alert_id	16578
datetime	2024-04-08 08:09:00
ra	203.853
dec	7.488
err	3
event_name	EP240327a
title	Detection of the X-ray source associated with SDSS J133519.91+072807.4 by Einstein Probe
content	We report on the independent detection of an X-ray source EP240327a by the Wide-field X-ray Telescope (WXT) on board the Einstein Probe (EP) mission. The observation began at 2024-03-27T09:51:02 (UTC) with a total exposure time of 2401 seconds. The position of the source is R.A. = 203.853 dec. DEC = 7.488 deg J2000) with an

relative alerts

TNS Alert: AT2019wzc

alert_from	TNS
alert_id	49658
datetime	2022-03-03 12:33:00
ra	203.833067
dec	7.46881605
separation(arcsec)	99.15
event_name	AT2019wzc
content	Discovery: 2019-12-13 13:36:00.000000 Magnitude: 18.66 (Filter: g) Internal names: ZTF19acnksky, ATLAS19bnp Reporting group: ZTF Reporters: J. Nordin, V. Brinnel, M. Glom, J. van Santen (HU Berlin), A. Gal-Yam, O. Yaron, S. Schulze (Weizmann) on behalf of ZTF Redshift: N/A Type: Unknown ADS Bibcode: 2019TNSTR2639...1N

from ZTF
used for source
identification

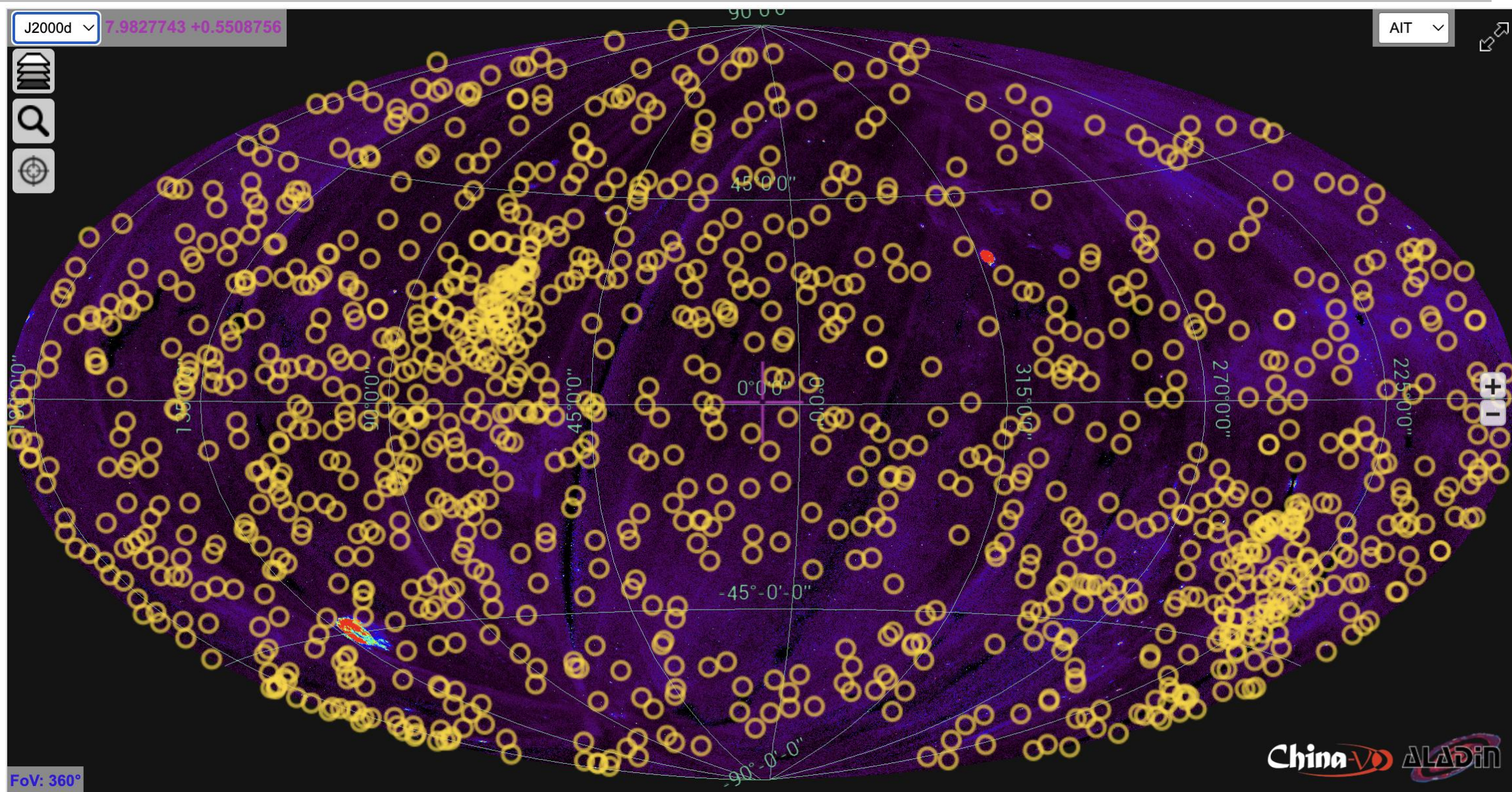


Q5: 天关卫星观测恒星耀发的情况如何?

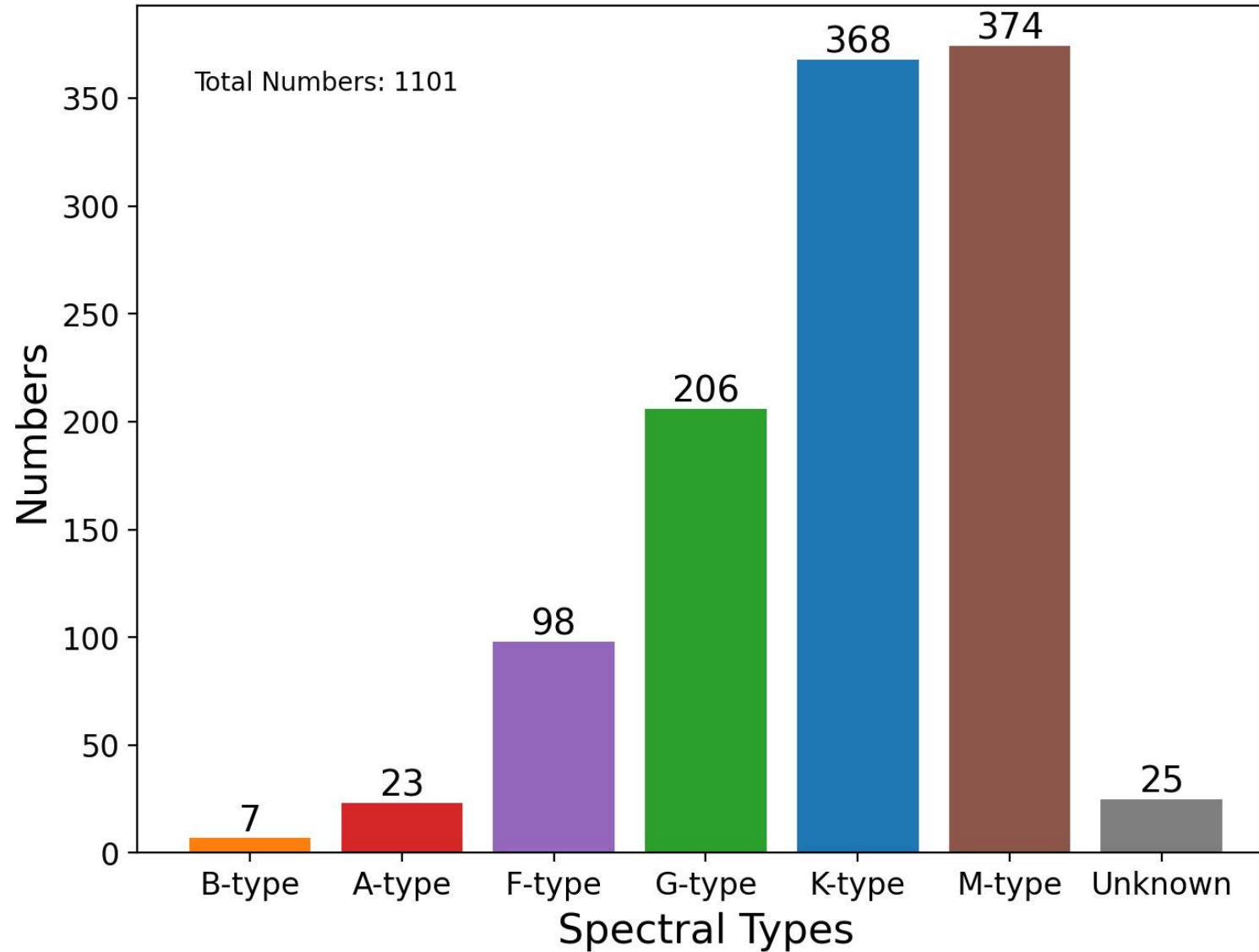
天关卫星 科学领域工作组（STP）

- STP1: Tidal Disruption Events (TDEs) and Active Galactic Nuclei (AGNs).
- STP2: Fast extragalactic transients (including gamma-ray bursts (GRBs) and non-GRB transients).
- STP3: Multi-messenger astronomy (synergies with gravitational wave events and with neutrino events).
- STP4: Compact stellar objects (compact objects including stellar mass black holes, neutron stars, and/or white dwarfs in our Galaxy or in nearby galaxies; ultra-luminous X-ray sources).
- STP5: Observatory Science (topics not included in the above panels, e.g., stellar flares, supernova remnants, diffuse emission, Solar System objects).
- STP6: Follow-up observation activities (not a science panel, but rather a structure within the EPST; any STP members can be involved and contribute to the follow-up activities).

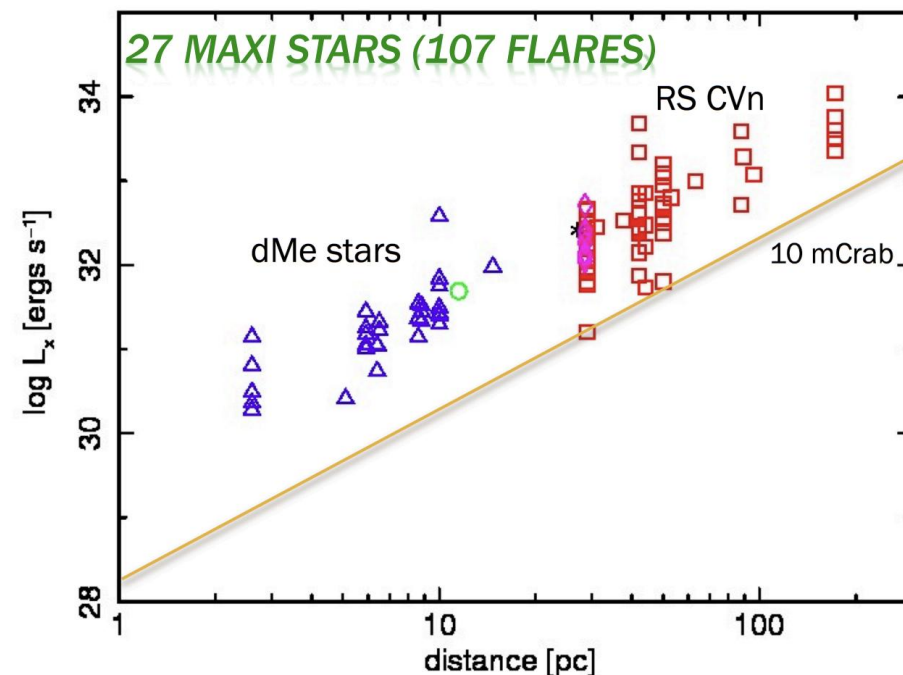
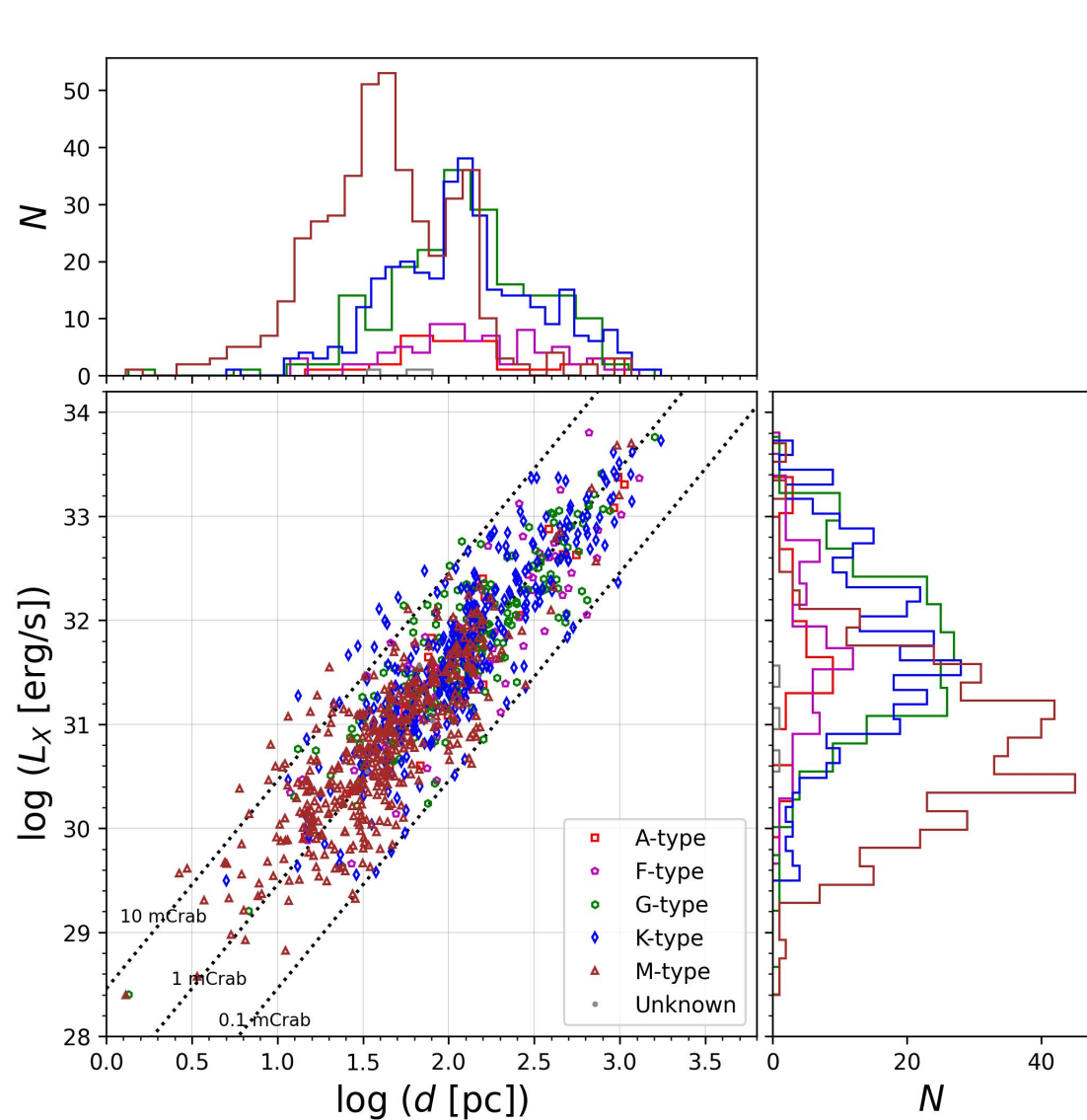
天关卫星对恒星耀发的观测(1000+)



spectral type distribution



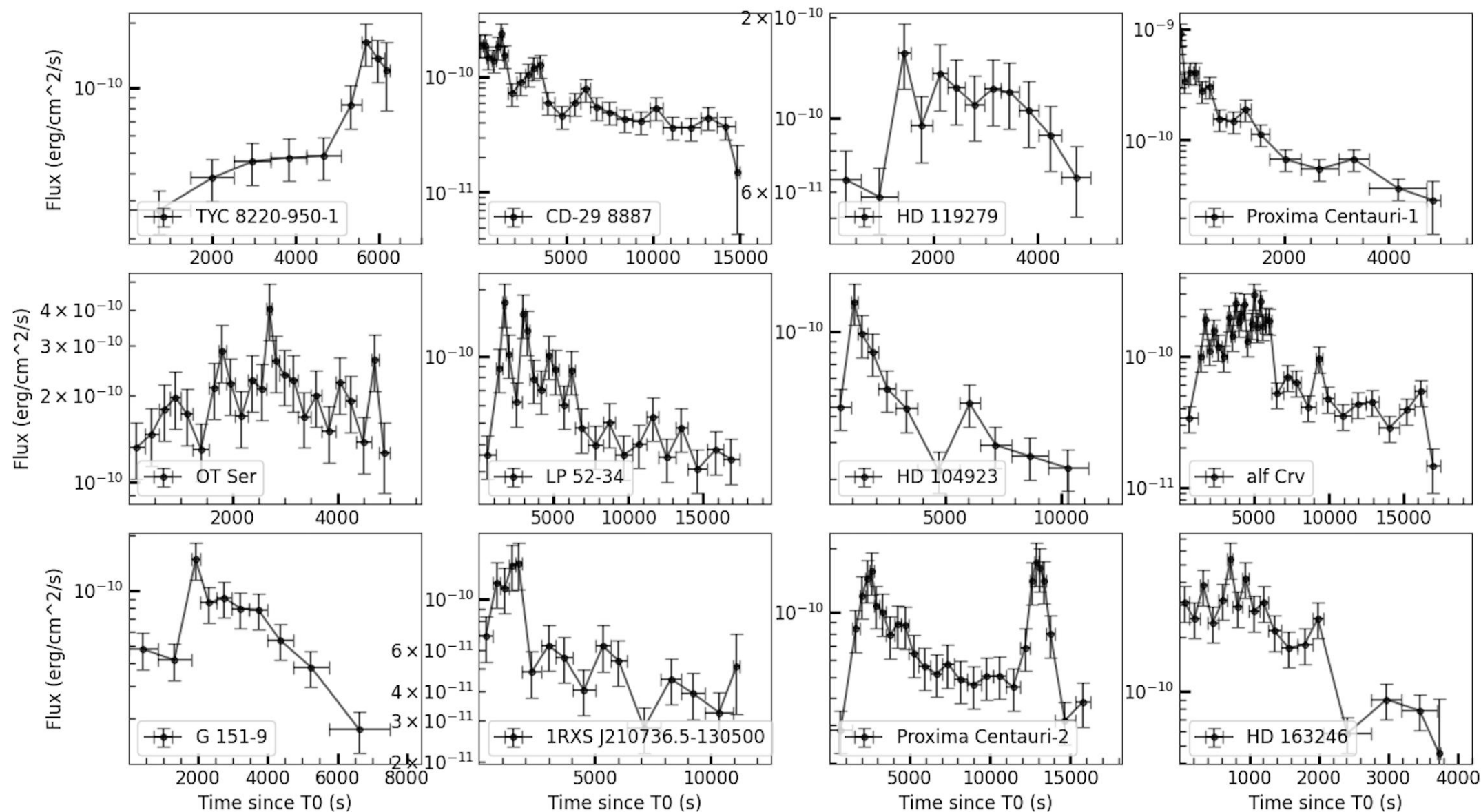
Luminosity versus distance distribution



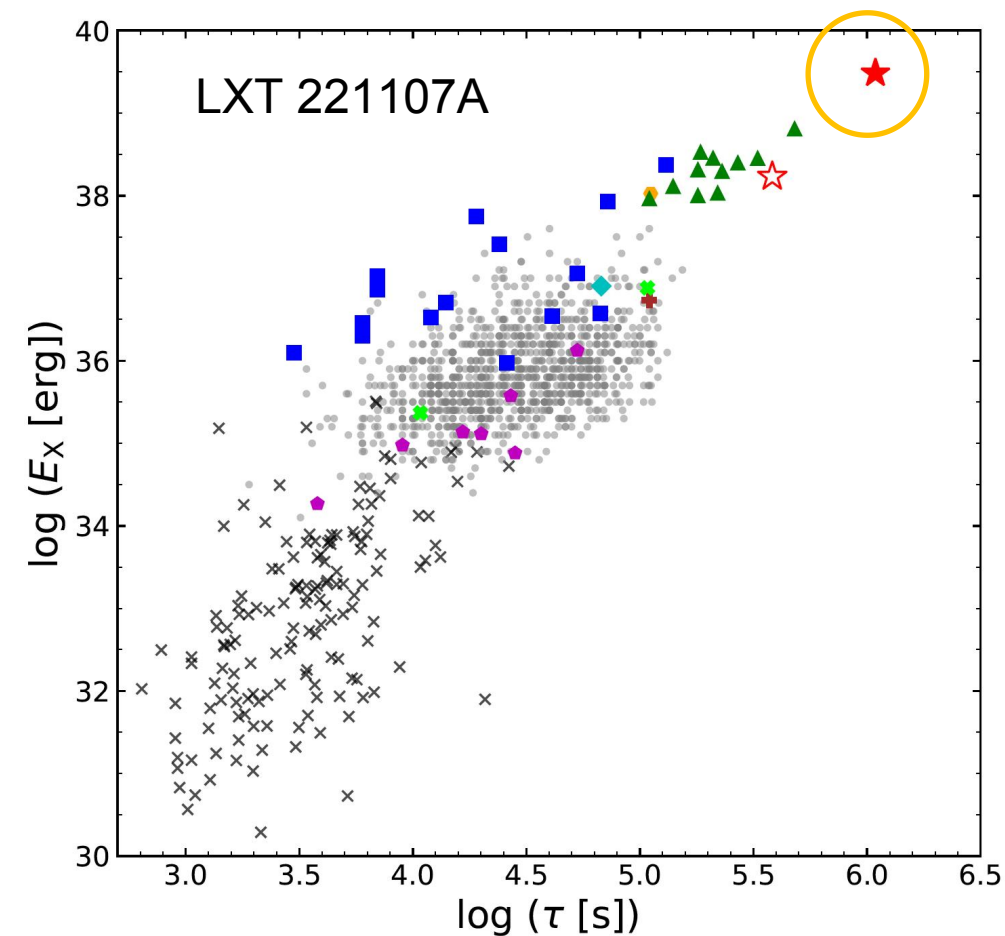
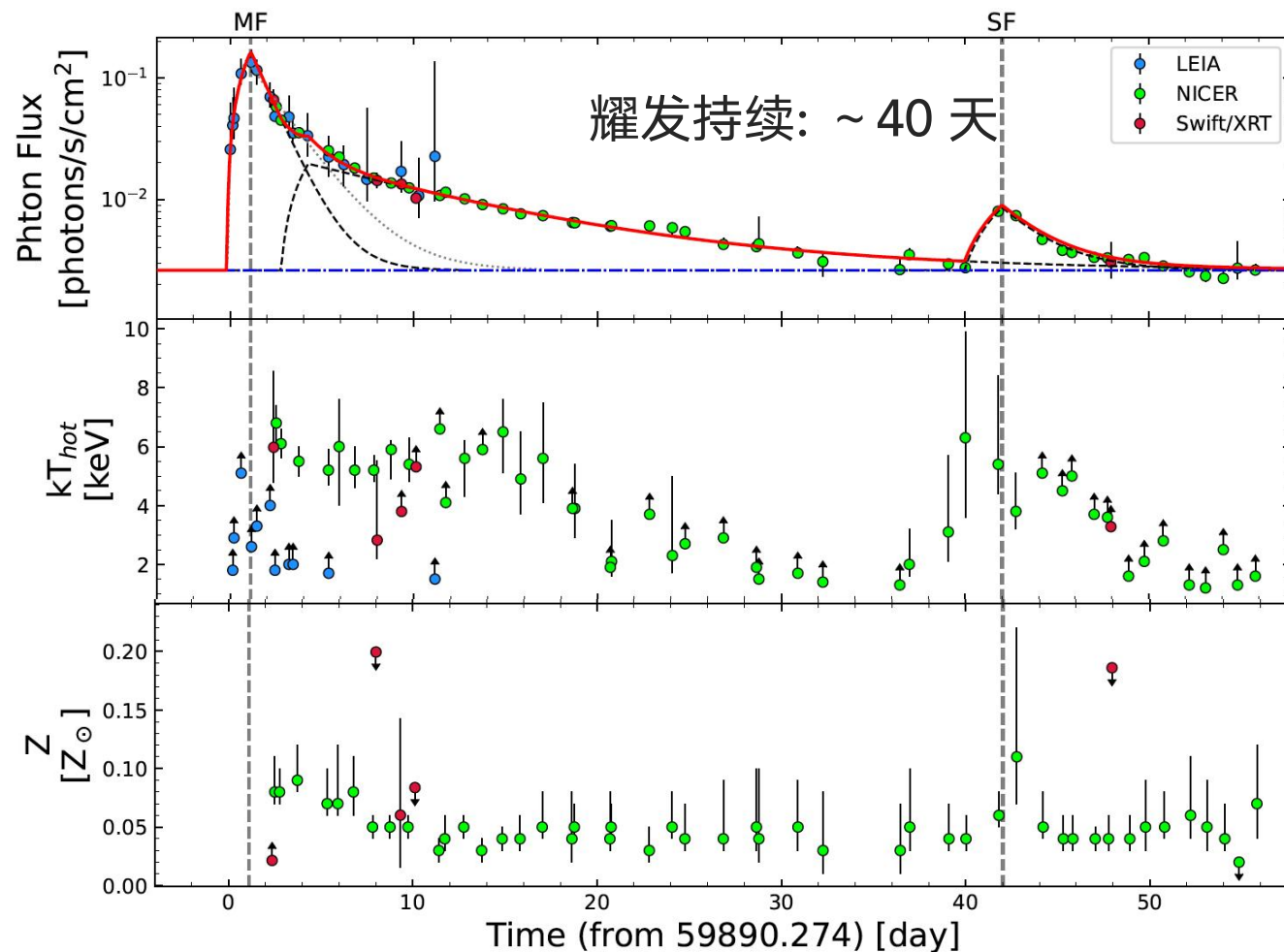
流量高于10 mcrab的恒星耀发事件较少

detection limit~0.1 mcrab

恒星X 射线耀发变曲线举例



LEIA 探测到迄今爆发能量最高、持续时间最长的恒星耀发



Peak L_X : $1.1E34$ erg/s (0.5-4keV); Energy: $3E39$ erg (0.5-4keV)

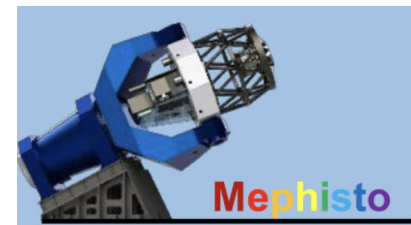
磁环长度 ~ 恒星直径;

Mao et al. 2025

天关卫星与其它项目团队合作



- 梦飞：目前已对M33和反银心天区进行协同观测；梦飞接收EP警报，已对20多个EP探测到的源进行了观测
- SVOM：双方已建立自动触发后随观测机制
- NICER：NICER团队将对EP探测到的高光度长时标恒星耀发源进行监测





Q6: 如何申请天关卫星观测/获取天关卫星数据?

Cycle-2 科学提案征集

EP Observing Proposal System (EOPS)

EP Observing Proposal Cycle-2: STP Observer Program

[Cycle-2 Proposer's Guidance](#)

STP Observer Program, including non-ToO observations and anticipated-ToO for known sources, opens to STP Member and Associate Member only. Please read the proposer's guidance carefully before submitting a proposal.

Create a new proposal

My proposal list

EP Observing Proposal Cycle-2: Guest Observer (GO) Program

[Cycle-2 Proposer's Guidance](#)

Guest Observer (GO) Program, including non-ToO observations and anticipated-ToO for known sources, opens to non-STP proposers whose primary affiliations are in China. Please read the proposer's guidance carefully before submitting a proposal.

[New ToO Observation](#)

My proposal list

[ToO Proposer's Guidance](#)

中国移动 15:56

无服务 5G 47%

×

...

征集指南

中国科学院国家天文台 2025年03月19日 17:03

北京 5人

各位同仁，

“天关”（爱因斯坦探针，EP）卫星科学中心于2024年底正式发布了“天关”卫星第二轮科学观测提案征集指南，提案在线提交系统已在2025年1月20日开放，截至日期为2025年4月4日。

诚挚地邀请各位感兴趣的同事（研究单位在中国，包括大陆及港澳台地区）积极申请。

提案申请网址：

https://ep.bao.ac.cn/ep/proposal_submit/user_proposal_create_guide

再次欢迎和感谢各位同仁使用“天关”卫星开展科学研究！

“天关”卫星科学中心

2025年3月19日



中国科学院国家...



18



42



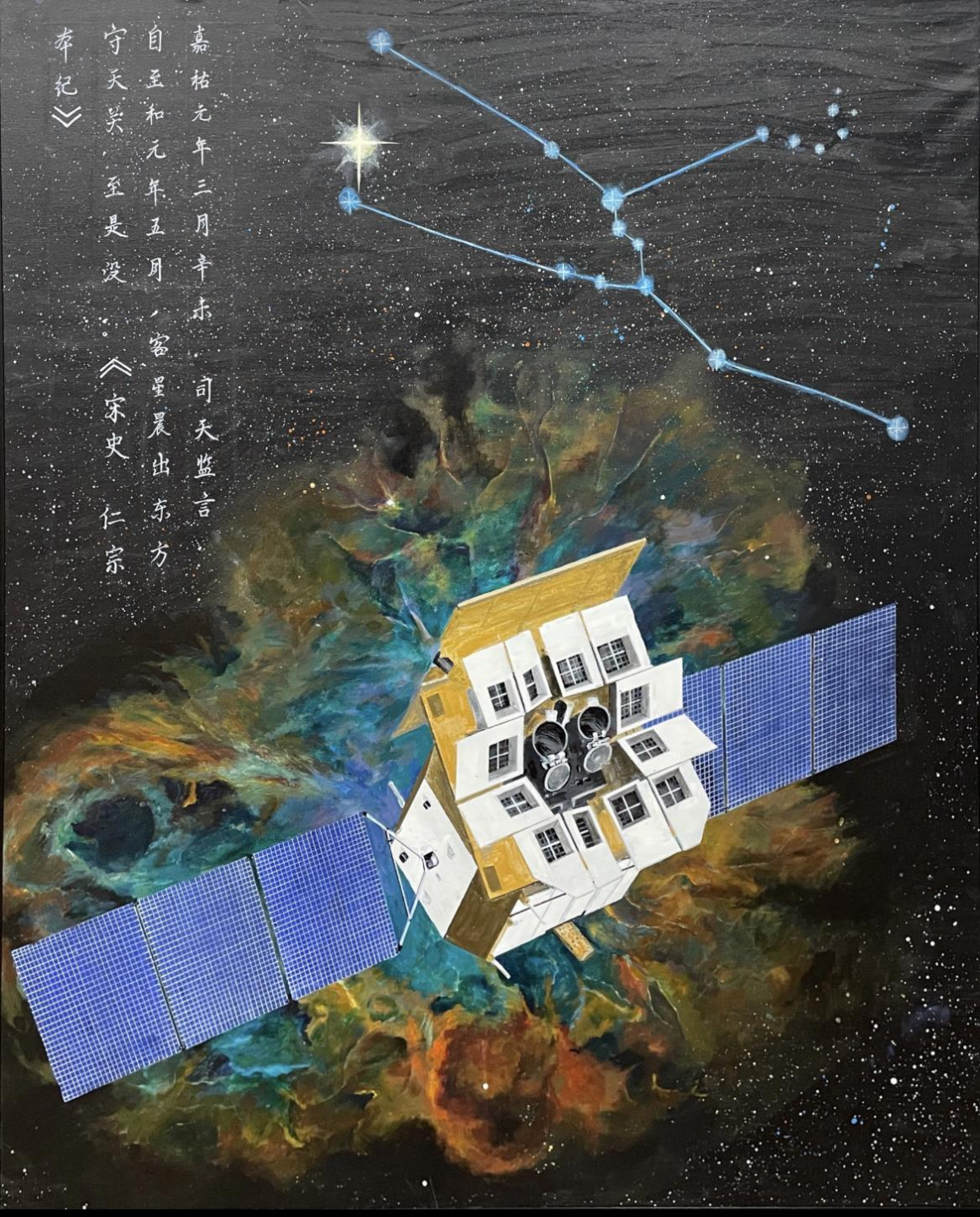
9



写留言

数据政策

- ◆ 暂现源警报信息： 立即发布
- ◆ 巡天和自主后随数据： 1年后公开（自2024年7月正式运行开始）
- ◆ EP源表： 定期发布
- ◆ ToO观测：
 - 科学团队申请： 6个月后公开
 - 外部成员申请： 立即公开
- ◆ ToO观测时间比例： CAS-ESA-MPE-CNES: 75% - 10% -10% -5%
- ◆ 外部成员与EP合作： 由SMC以及每个STP chair/co-chair 讨论决定



嘉祐元年三月辛未 司天監言
自至和元年五月，客星晨出东方
守天哭，至是没。《宋史 仁宗
本紀》

谢谢大家！





PV observations

□ Performance Verification (PV):

✓ Observation Time: 2024.3.22 ~ 2024.4.5

✓ Proposals: 17

✓ Targets: 17

✓ Duration: ~10 days

PV Targets and Schedule

Source Name	RA	Dec	Proposed Duration	Time Start (UTC)	Time Stop (UTC)	FXT-A Mode	FXT-B Mode	Contact Person	Status
WXT All-sky Survey	/	/	2 days	2024-03-22T00:58:04	2024-03-24T01:09:11	FF-thin	FF-thin	Yuan Liu	Observed
1LHAASO J1740+0948u	265.03	9.81	10000 s	2024-03-24T01:09:11	2024-03-24T07:33:55	FF-thin	FF-thin	Haiwu Pan	Observed
M86 pointing 2	186.3875	13.061944	20000 s	2024-03-27T09:27:29	2024-03-27T22:18:20	FF-thin	FF-thin	Jeremy Sanders	Observed
Galactic Center	266.416792	-29.007833	30000 s	2024-03-27T22:18:20	2024-03-28T19:10:58	FF-thin	FF-thin	Chichuan Jin	Observed
Lockman Hole	161.25	58	60000 s	2024-03-28T19:10:58	2024-03-30T06:23:55	FF-thin	FF-thin	Chichuan Jin	Observed
A3571	206.902792	-33.034642	35000 s	2024-03-30T06:23:55	2024-03-31T06:28:38	FF-thin	FF-thin	Heng Yu	Observed
1LHAASO J0428+5531	66.63	54.63	10000 s	2024-03-31T06:27:38	2024-03-31T13:01:02	FF-thin	FF-thin	Haiwu Pan	Observed
A1795 pointing 2	206.333333	26.595556	40000 s	2024-03-31T13:01:02	2024-04-01T14:42:23	FF-thin	FF-thin	Yong Chen	Observed
4U 1728-34	262.990542	-33.834028	20000 s	2024-04-01T14:42:23	2024-04-02T03:33:03	TM-medium	TM-medium	Alessio Marino	Observed
M86 pointing 1	186.54875	12.946222	20000 s	2024-04-02T03:33:03	2024-04-02T16:32:13	FF-thin	FF-thin	Jeremy Sanders	Observed
1E 1547.0-5408	237.7255	-54.306694	15000 s	2024-04-02T16:32:13	2024-04-03T00:25:21	PW-thin	PW-thin	Francesco Coti Zelati	Observed
1E 1547.0-5408	237.7255	-54.306694	15000 s	2024-04-03T00:25:21	2024-04-03T13:15:59	FF-thin	FF-thin	Francesco Coti Zelati	Observed
4U 1636-536	250.231658	-53.751375	10000 s	2024-04-03T13:15:59	2024-04-03T19:41:17	TM-medium	PW-medium	Renxin Xu, Guobao Zhang, Rongfeng Shen	Observed
W28 pointing 1	270.27	-23.49	18000 s	2024-04-03T19:41:17	2024-04-04T08:31:54	FF-thin	FF-thin	Fangjun Lu	Observed
W28 pointing 2	269.73	-23.49	18000 s	2024-04-04T08:31:54	2024-04-04T19:46:11	FF-thin	FF-thin	Fangjun Lu	Observed
A1795 pointing 1	207.220833	26.595556	10000 s	2024-04-04T19:46:11	2024-04-05T00:35:10	FF-thin	FF-thin	Yong Chen	Observed
4U 0614+091	94.280417	9.136944	15000 s	2024-04-05T00:35:10	2024-04-05T11:49:27	PW-medium	PW-medium	Chandreyee Maitra	Observed

Proposal ▾

Activities

Observing Proposal System

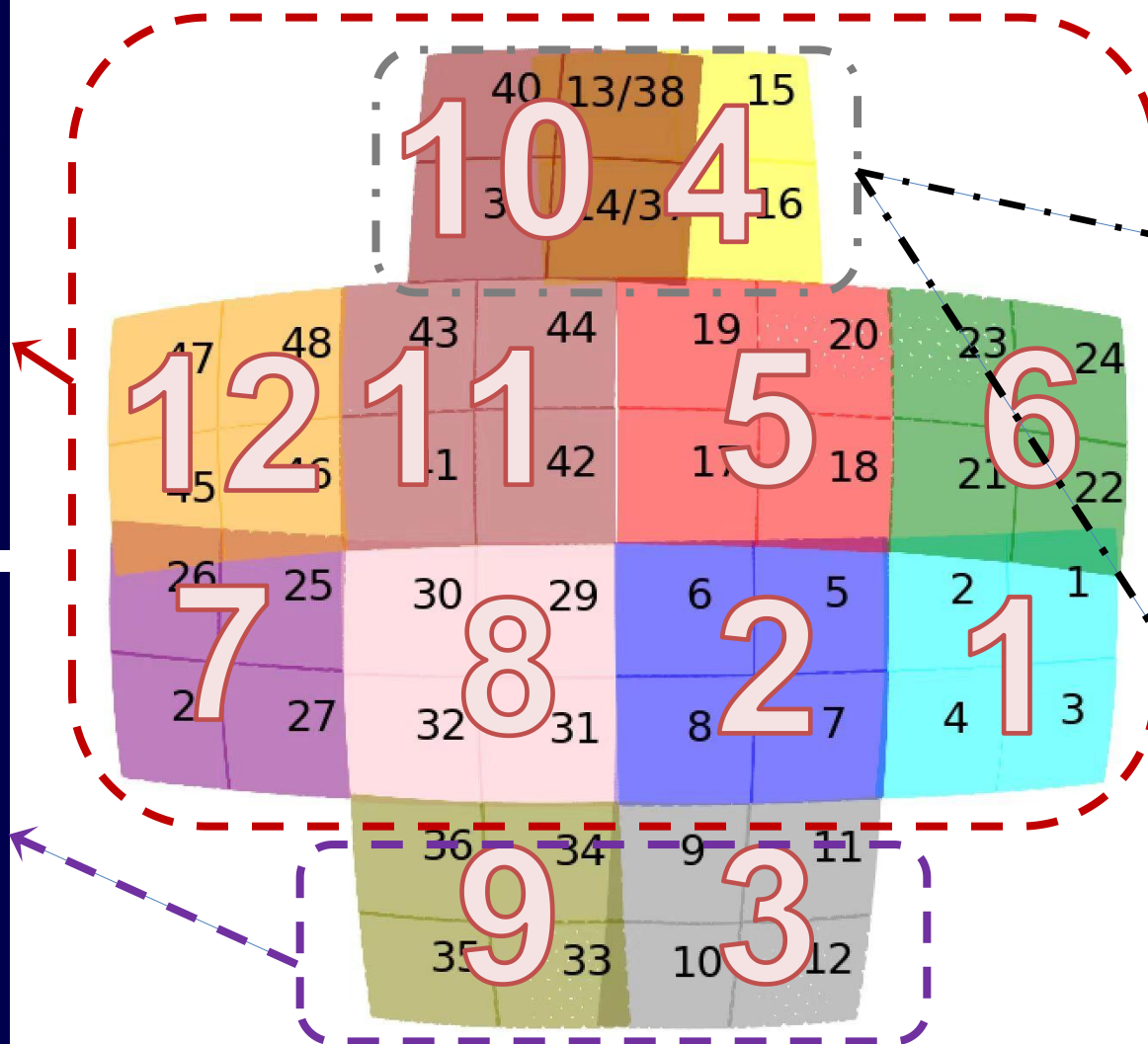
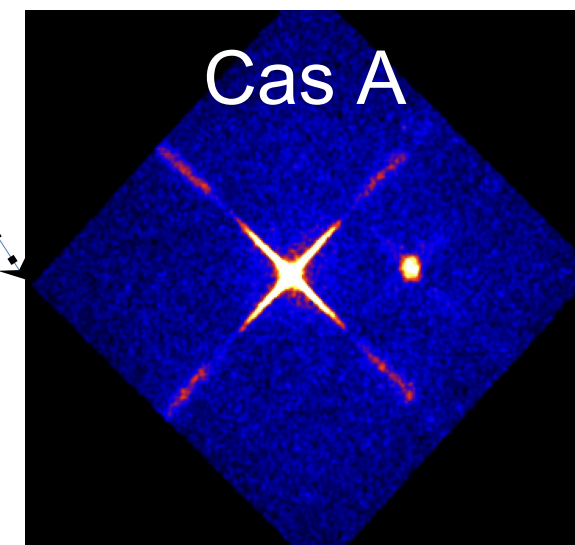
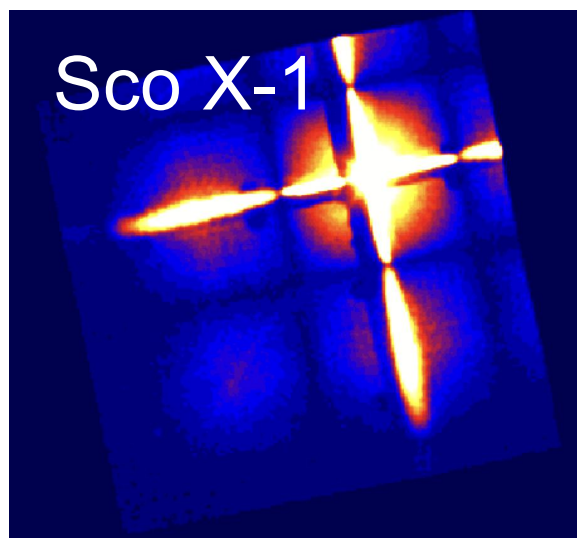
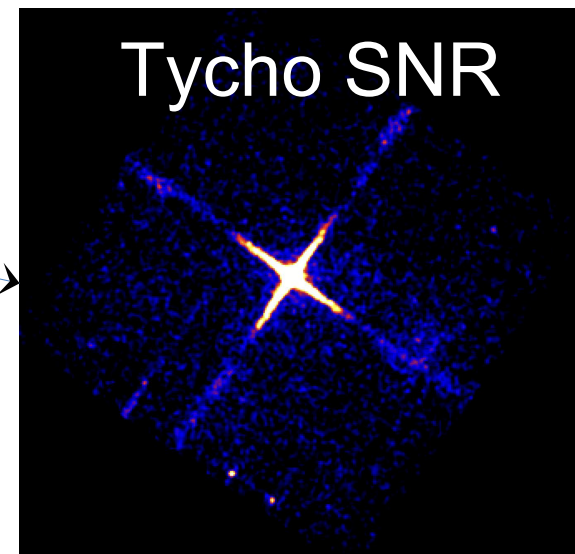
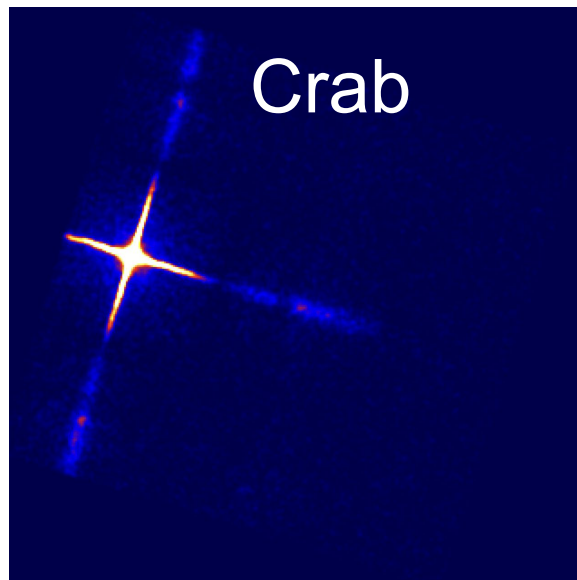
PV Targets and Schedule

Proposal Call

Approved Cycle-1 Sources

FXT Gap-filling Source List

2024年5月：基本完成WXT12个模块的在轨定标



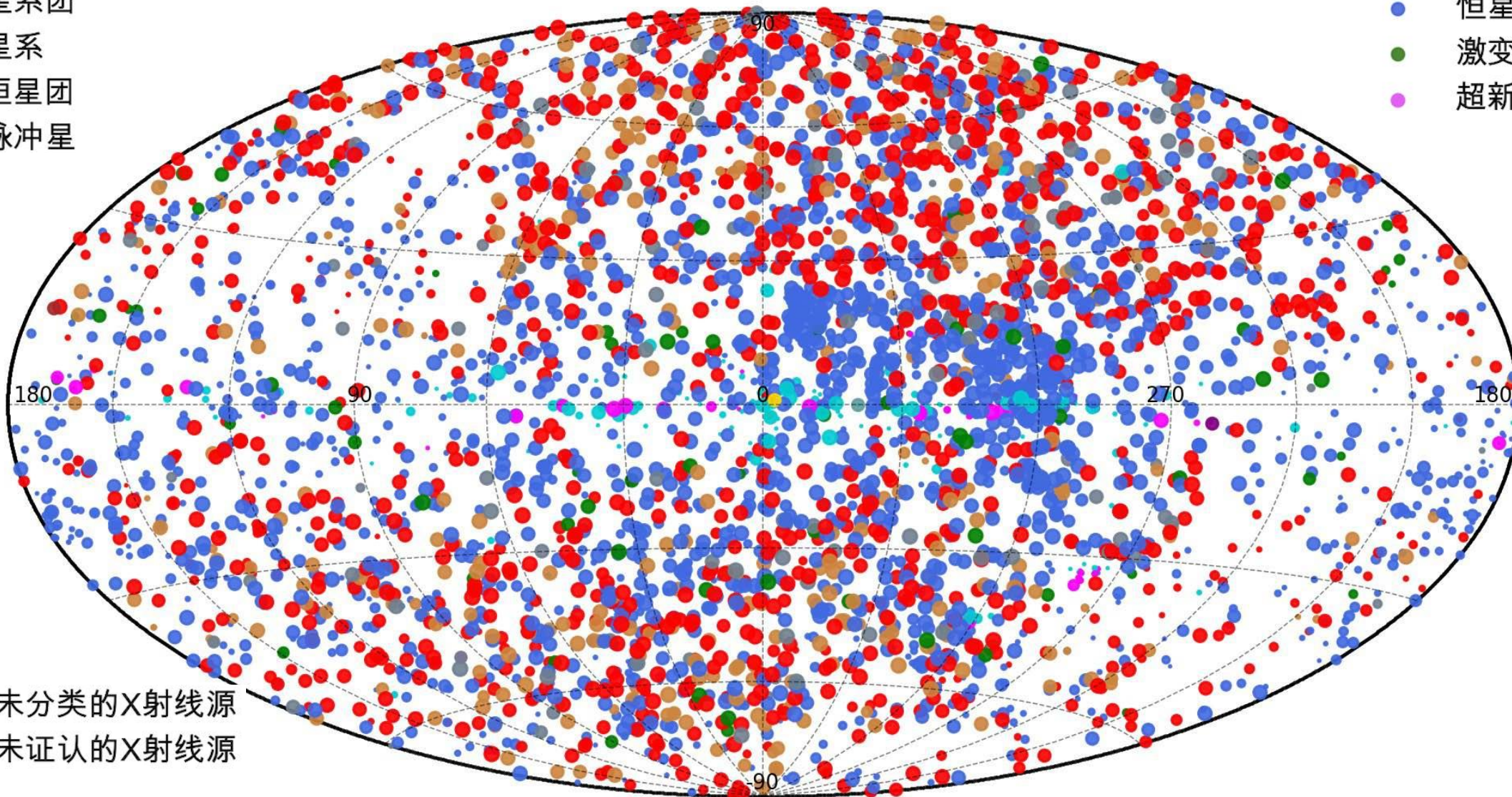
EP-WXT 探测到的 X 射线源 (亮源)

总的源探测数: 6867

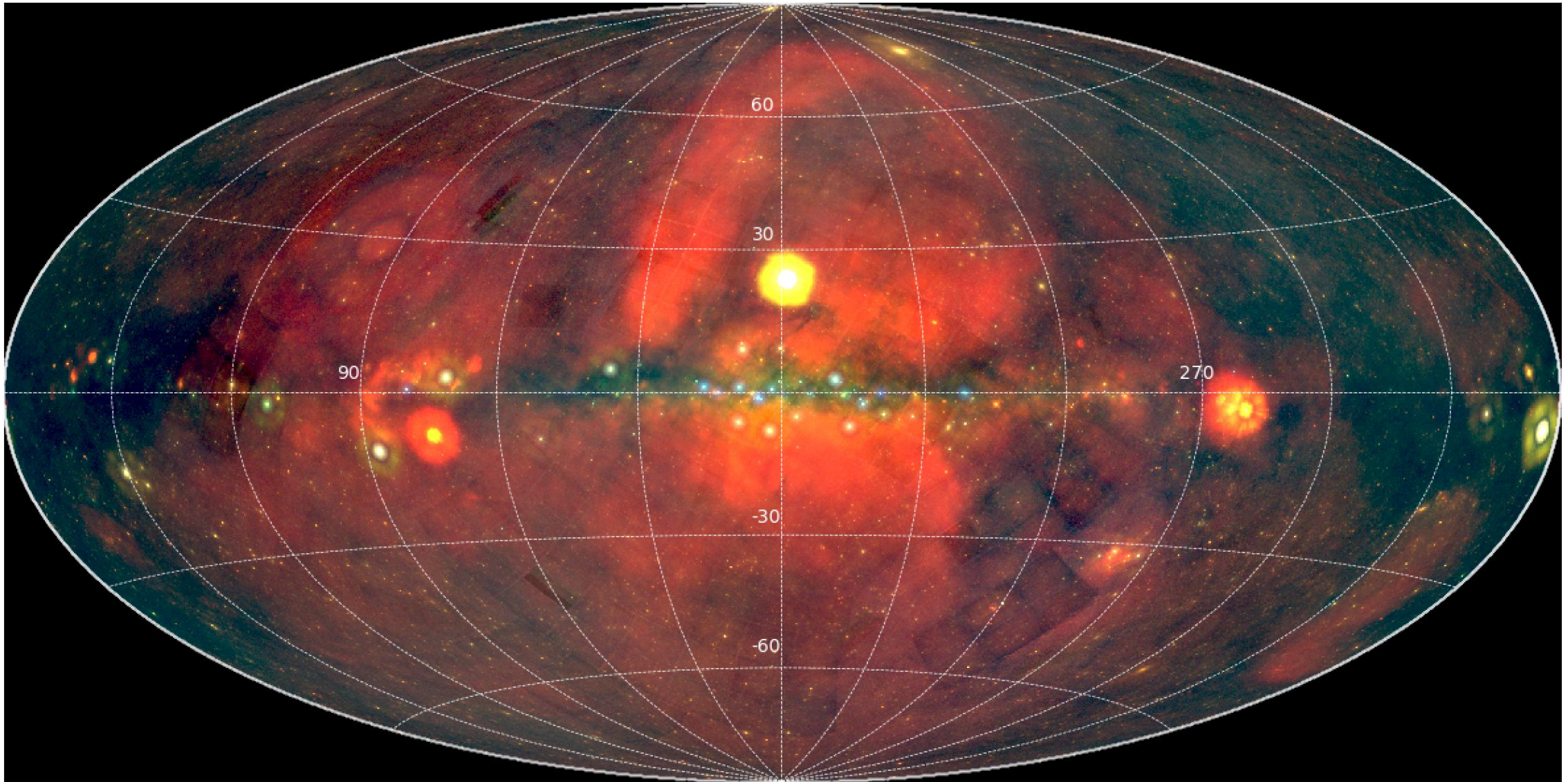
- X射线双星
- 星系团
- 星系
- 恒星团
- 脉冲星

- 活动星系核
- 恒星
- 激变变星
- 超新星遗迹

- 未分类的X射线源
- 未认证的X射线源



WXT X射线全天天图



引导了多个国际天文设备的观测研究

- Chandra, XMM-Newton, NICER, Swift, NuSTAR (X-ray)
- Keck, Gemini, VLT, GTC, NOT, Xinglong-2.16m, 2m4, SOAR, KAIT, Mephisto (Optical)
- TNG, GROND, WIRC (Near-IR)
- MeerKAT, ATCA, e-MERLIN (Radio)



发布200 多条GCN 和 Atel 天文警报，引导了多个国际上地面和空间多波段设备后随观测