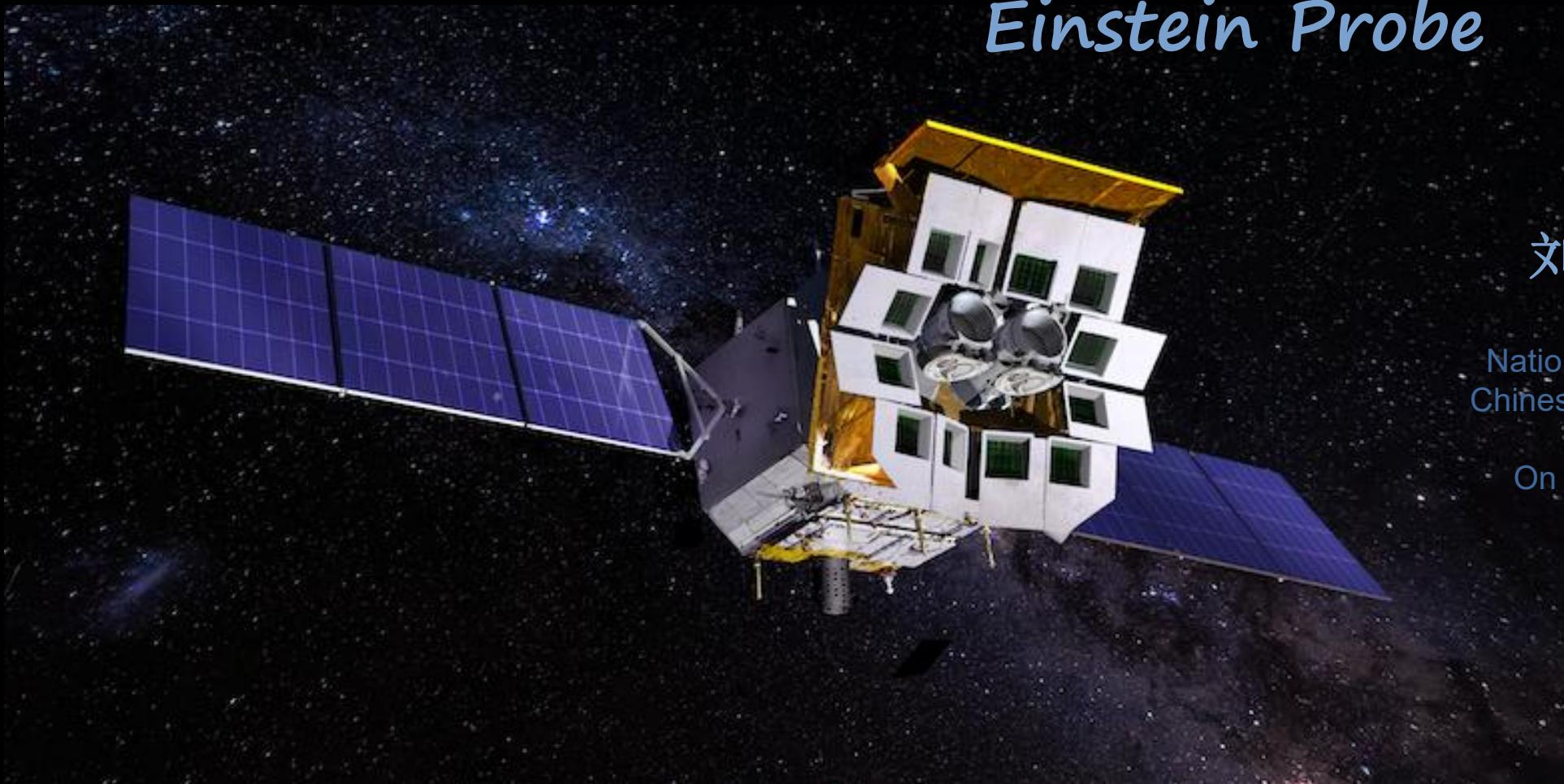




中国科学院
CHINESE ACADEMY OF SCIENCES



*Exploring the ever-changing X-ray Universe
Einstein Probe*



刘元 Yuan Liu

National Astro. Observatories
Chinese Academy of Sciences

On behalf of EP consortium

New high-energy transients & science questions

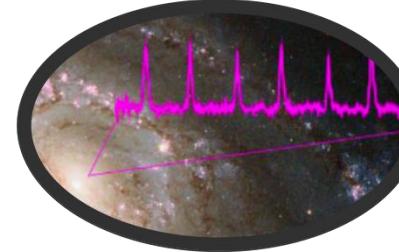
BH tidal disruption event

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

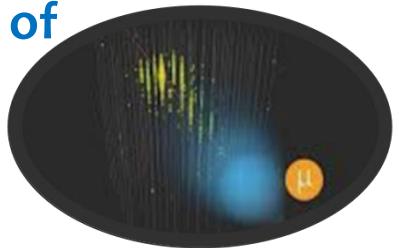


Small numbers of known objects

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?



Einstein Probe (EP) mission of CAS



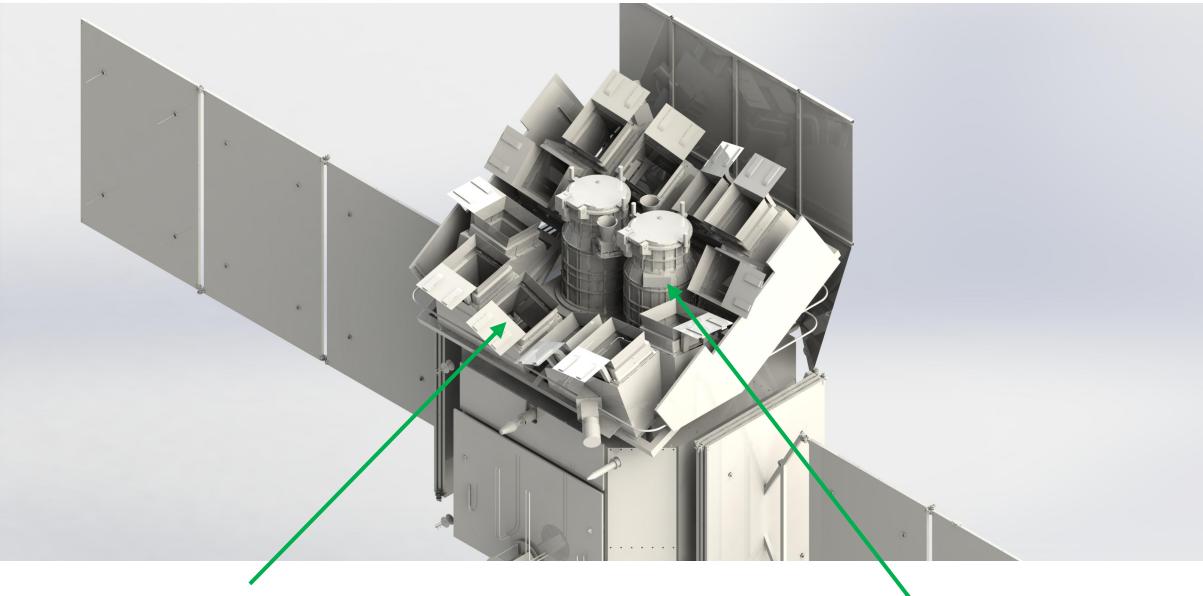
EP science goal

X-ray all-sky monitoring to discover & characterise high-energy transients, and to monitor variability of X-ray sources, at sensitivity > 1 order of magnitude better than current ones

- 2012: EP proposal
- Adoption: 2017-12
- CDR: 2022-03
- Current in phase D (Flight Model)
- Planned launch: by the end of 2023
- Lifetime: 3 years (goal 5 yr)
- International collaboration: ESA & MPE (+CNES)



Instruments & SC



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



lobster-eye MPO
FoV: 3600 sq deg (1.1 sr)
band: 0.5 – 4 keV
spatial resolution: ~ 5' (FWHM)
sensitivity: tens times better than current

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



Wolter-1 optics
FoV: ~1 deg
band: 0.3-10 keV
effective area: 300 cm² @1 keV (1 unit)
spatial resolution: 30" (HPD on-axis)

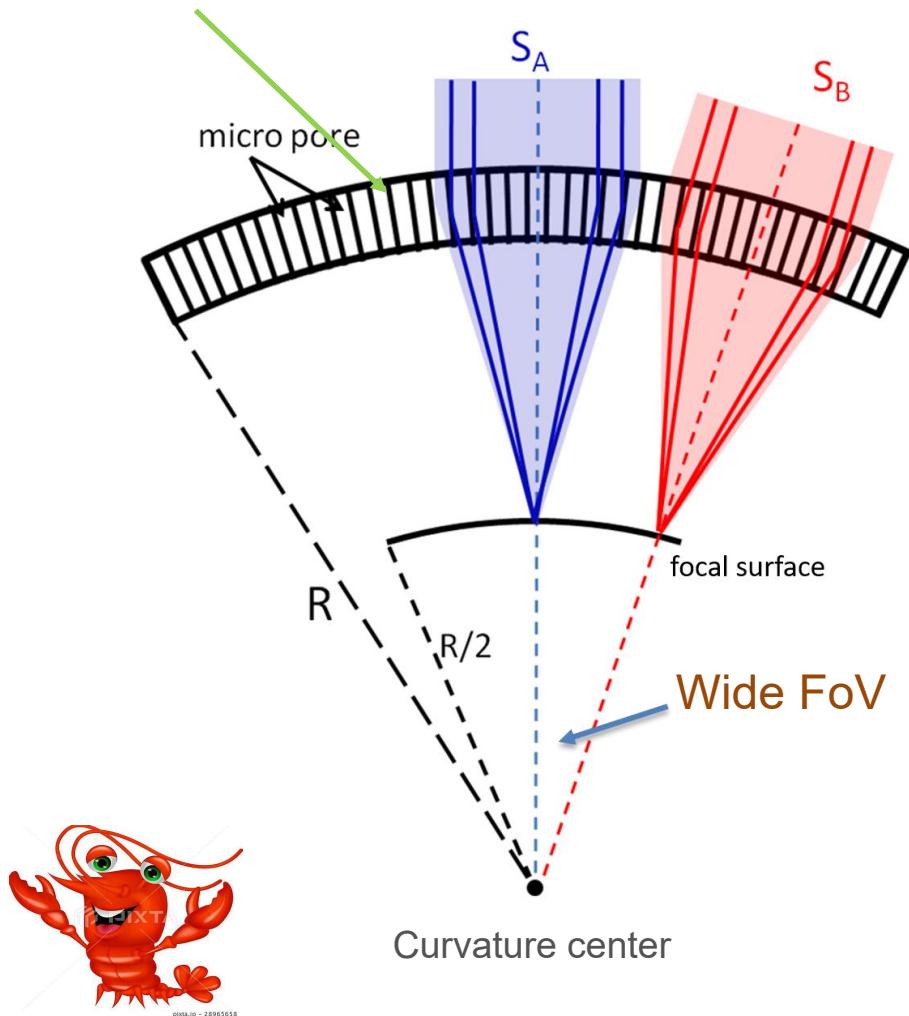
Spacecraft



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

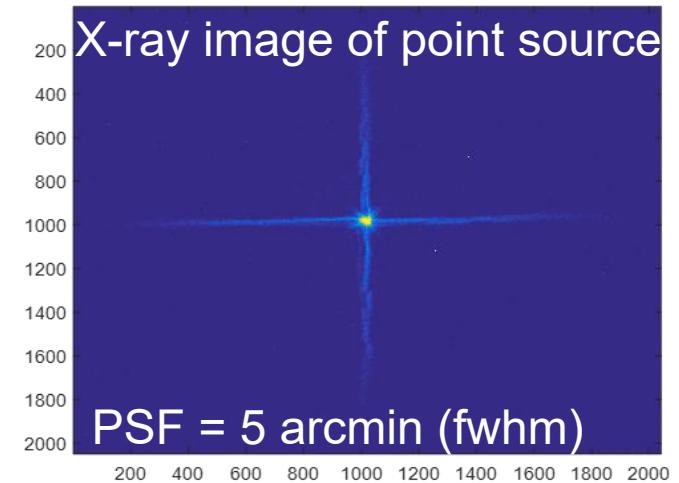
Lobster-eye micro-pore optics (MPO) for X-ray focusing

grazing incidence reflection



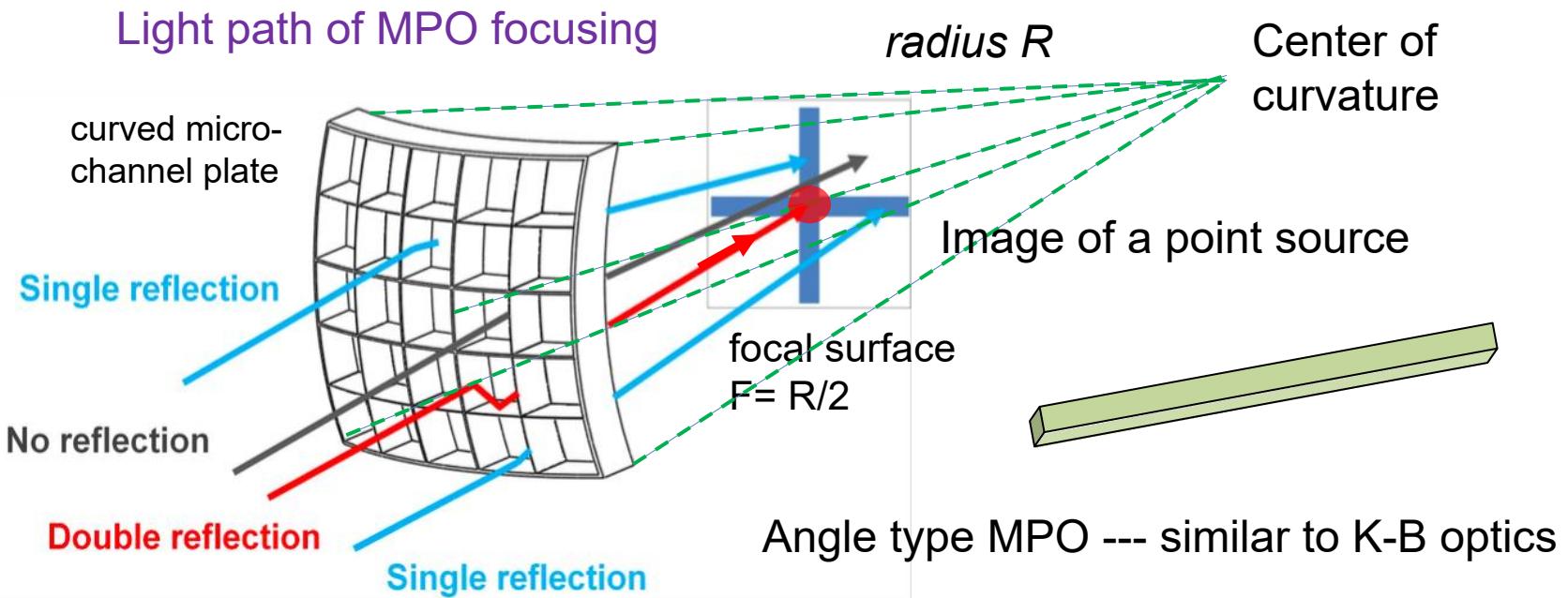
ideal optics for X-ray wide-field monitors

- ✿ wide field of view
- ✿ better angular resolution (5 arcmin)
- ✿ higher sensitivity
- ✿ optimised in soft X-ray

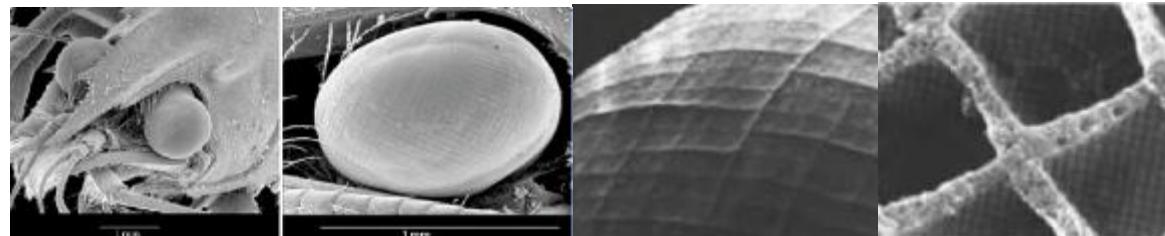


first proposed by R. Angel (1979); studied by a number of groups for many years e.g. Wilkins et al. (1989) ; Fraser et al. (1992); Kaaret (1992), also at NAOC since 2010

X-ray focusing optics: Micro-Pore Optics - Angel



Lobster eye

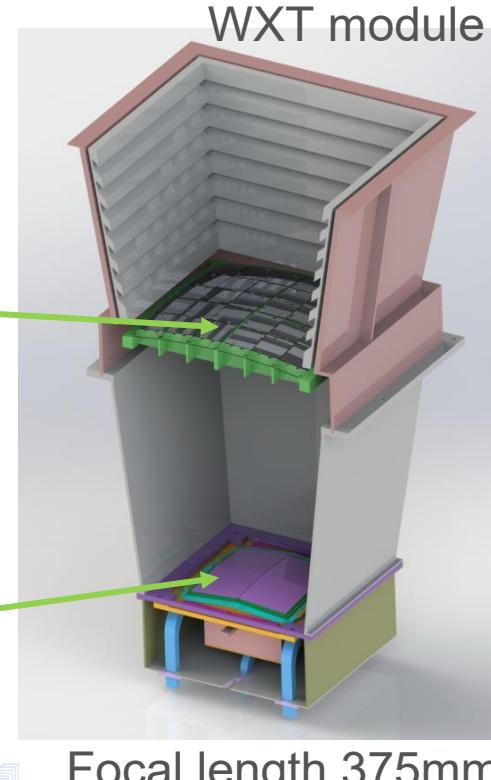
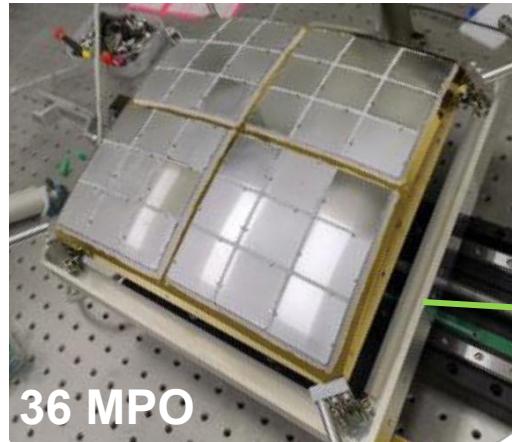


(also other crustaceans)

SEM image (Gaten 1994)

*Lobsters see by light reflection (grazing incidence)
rather than refraction !*

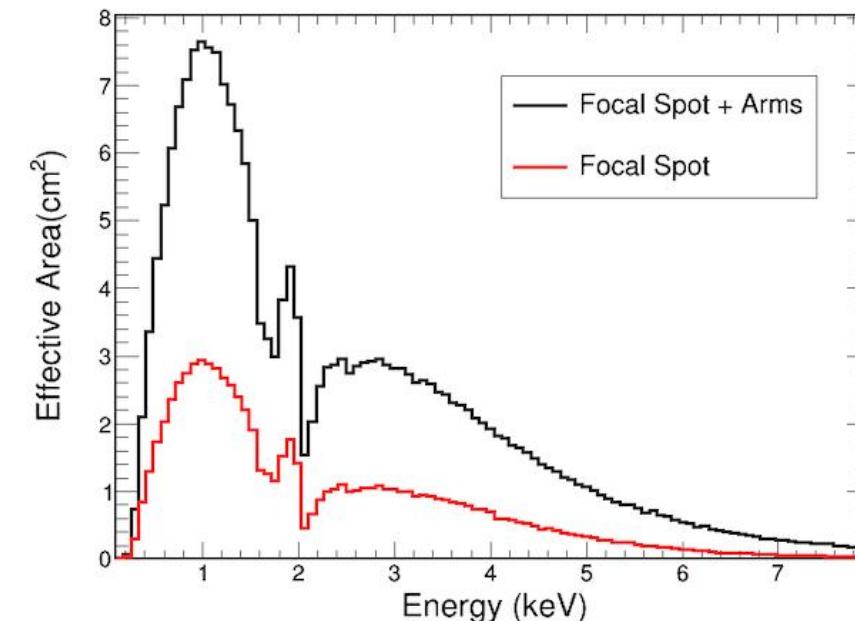
Wide-field X-ray Telescope (WXT)



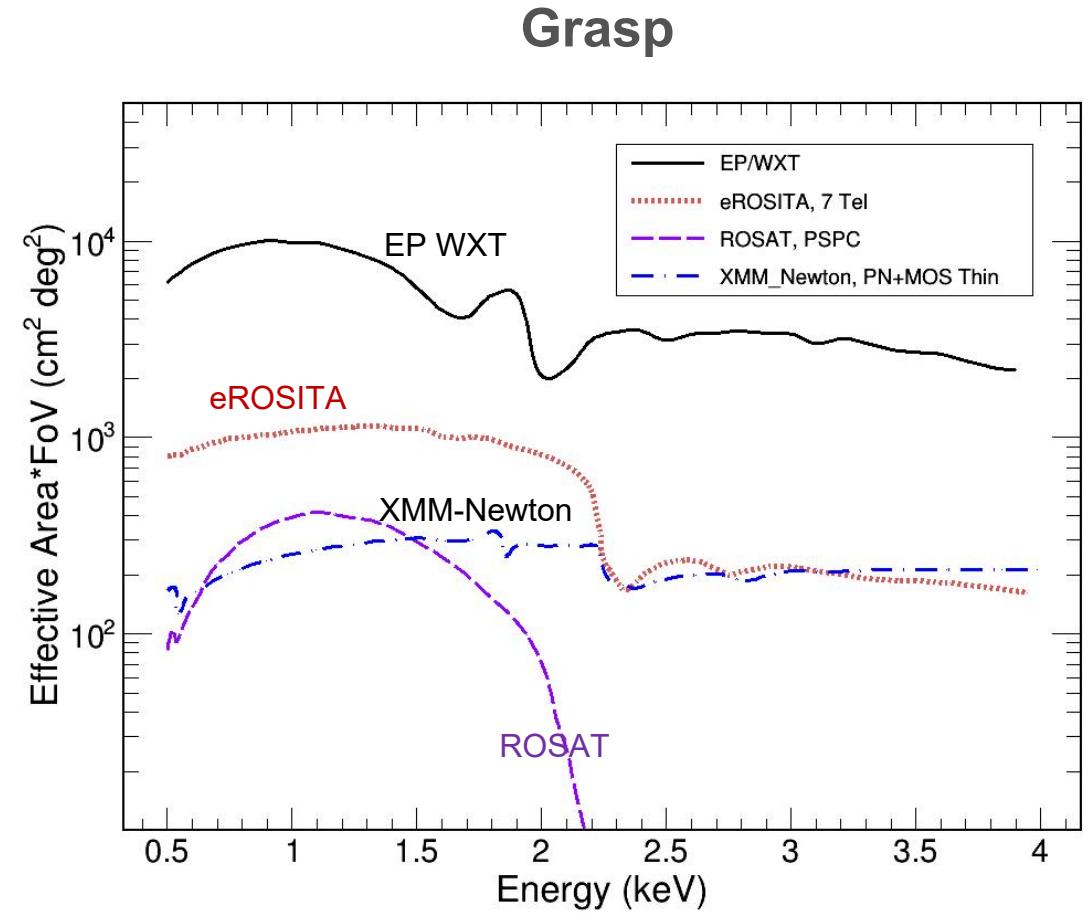
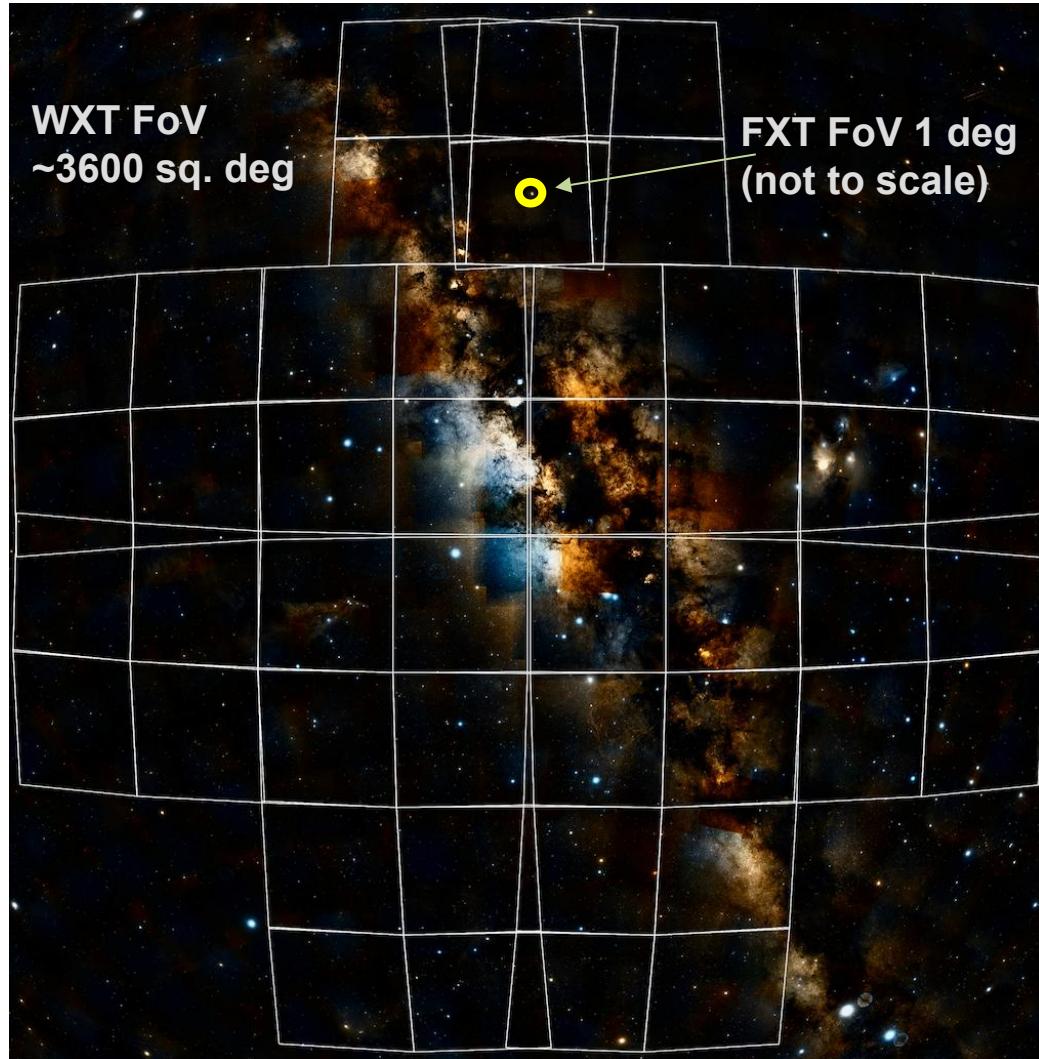
- development: CAS (SITP, NAO) + NNVT
- test/calibration: CAS & ESA
- WXT PI: X. Sun (SITP);
- Instr. Sci: Z. Ling (NAO); MA PI: C. Zhang (NAO)

Technology challenges

- First large-FoV MPO telescope (432 plates)
- Large detector array (48 CMOS x 6 x 6 cm²)
- Use of CMOS as X-ray detectors in space
- Soft X-ray band

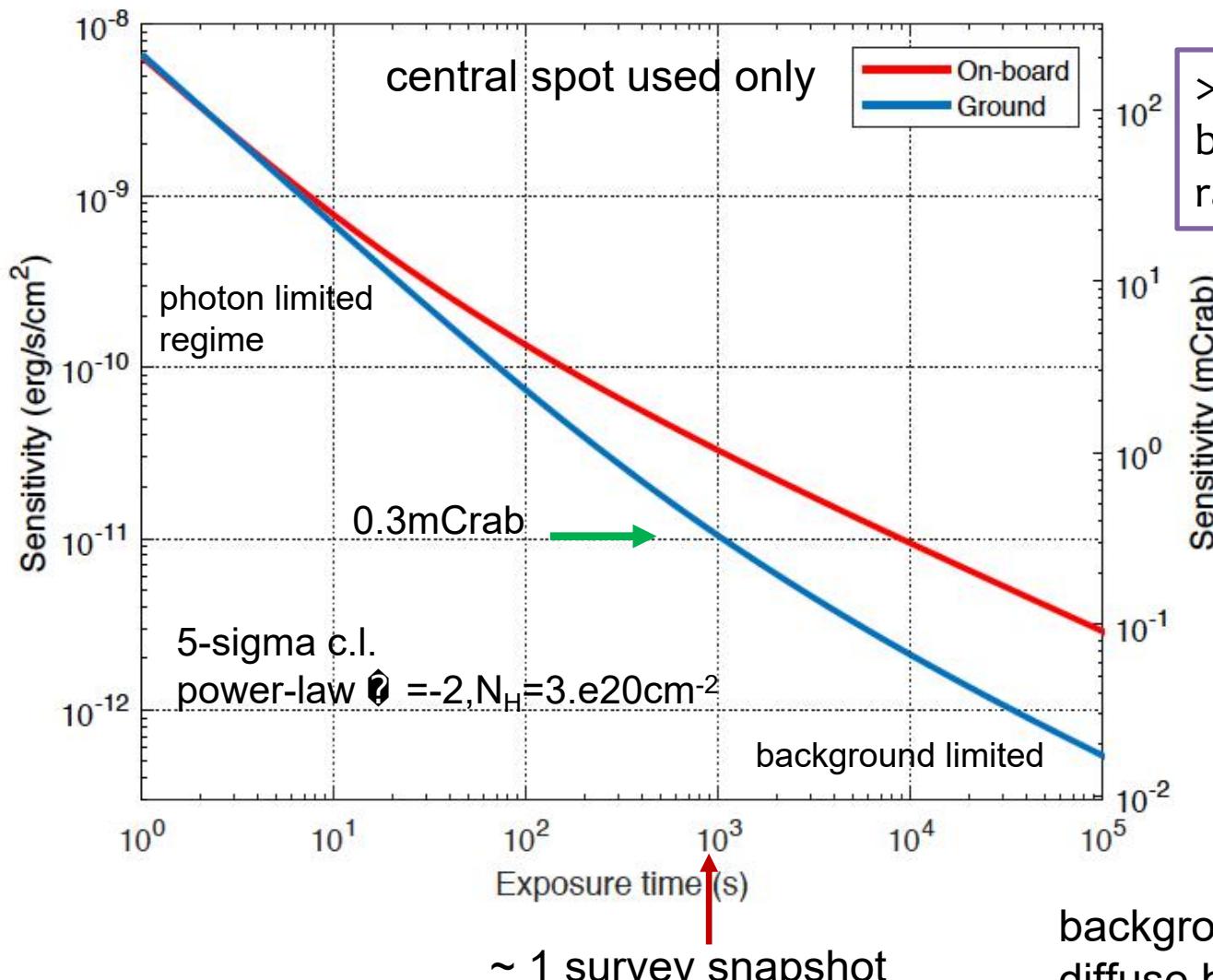


WXT FoV & Grasp



Zhao D. et al. 2017

Simulated EP WXT sensitivity



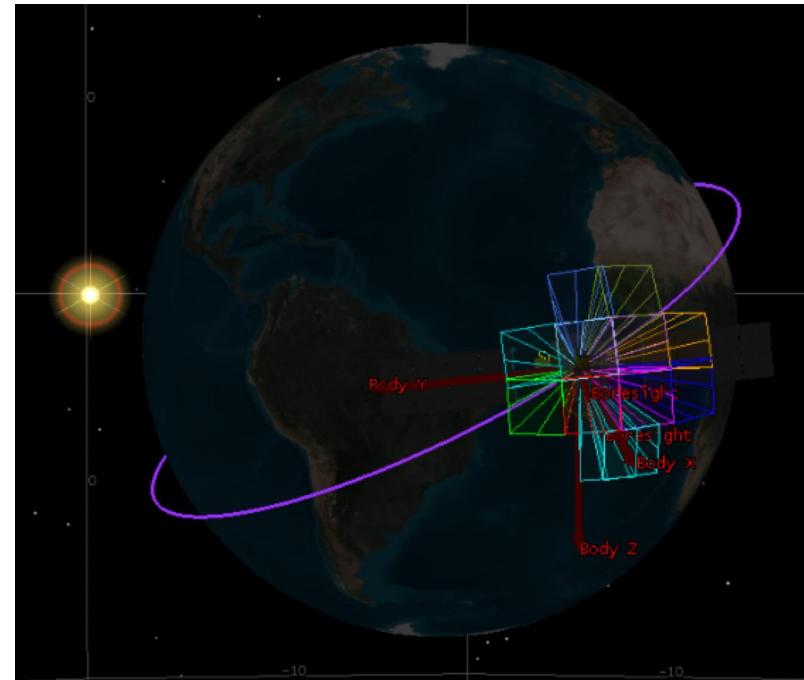
> 1 order of magnitude better than current X-ray ASM (MAXI, Swift)

backgrounds : particles,
diffuse background, with
shielding

Zhao D. et al. 2017

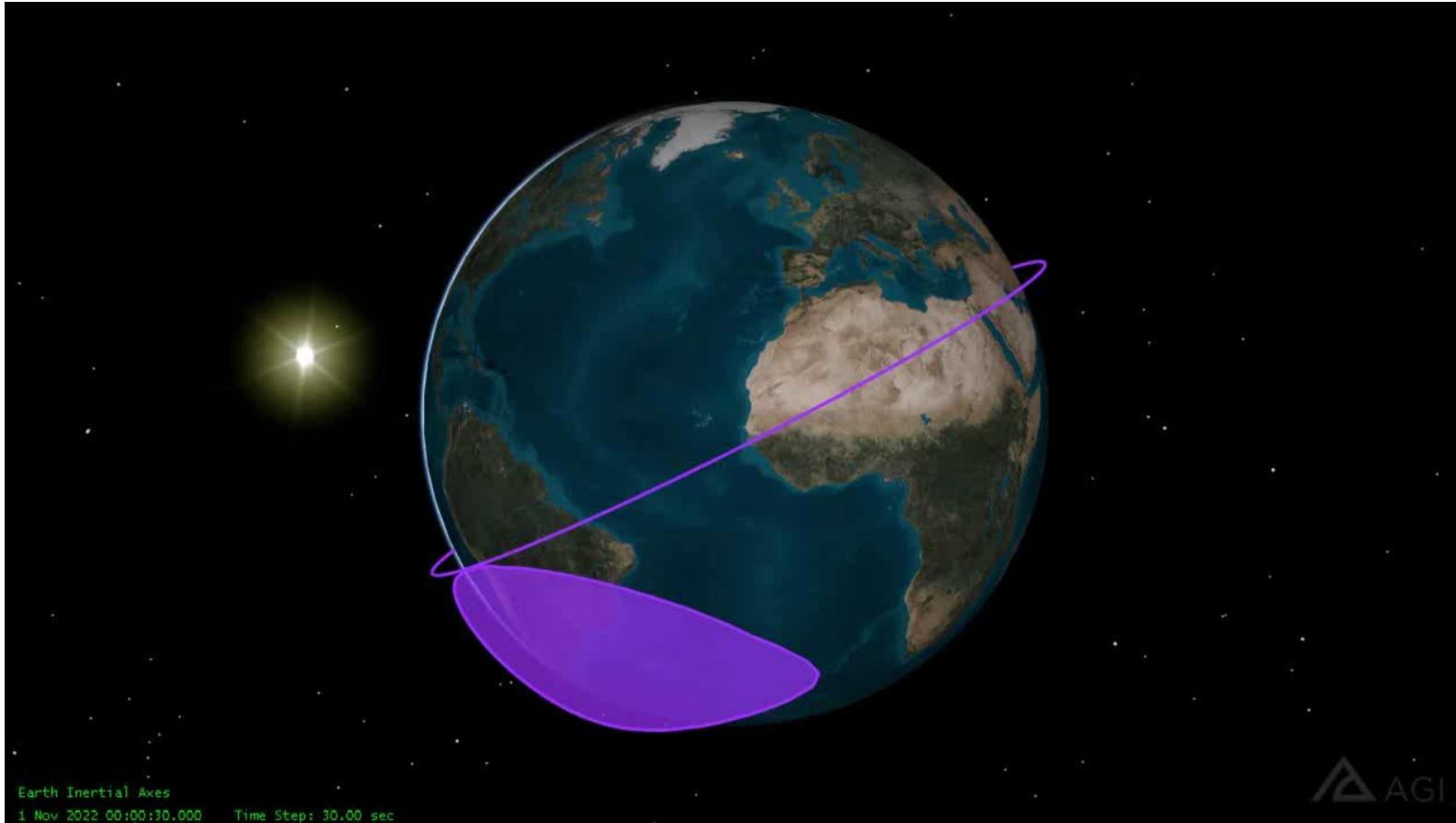
Mission profile

- Orbit: ~ 600 km (96min), incl. 29 deg
- Operation modes
 - Survey (WXT)
 - Autonomous X-ray follow-up (FXT)
 - Target of opportunity (FXT, WXT)
- Alert data rapid downlink
 - Beidou system (China)
 - VHF (CNES/France)
 - Transient alert information to be released immediately and publicly
- Target of opportunity command uplink
 - Normal (S-band): < 1 day
 - Time critical (Beidou): < 10 min

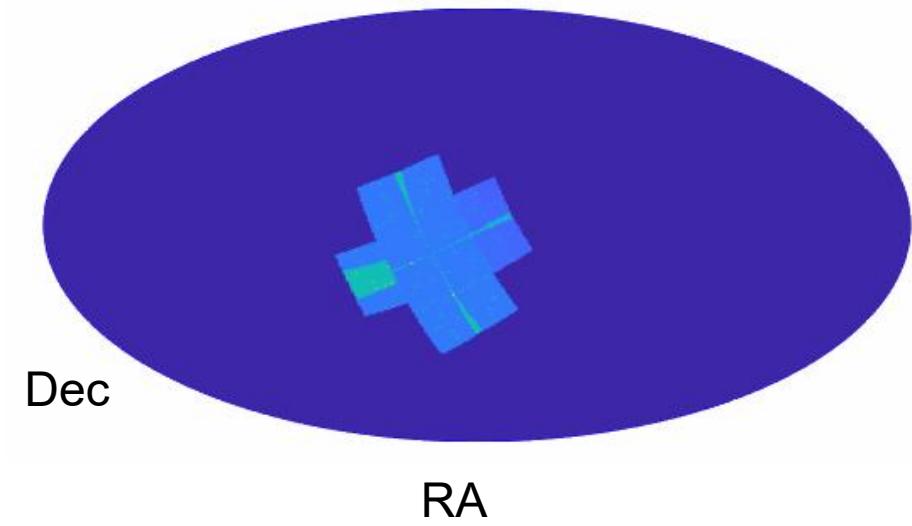


- EP Mission Centre @ NSSC/CAS
ESA (GS telemetry support)
- EP Science Centre @ CAS
NAOC+IHEP

EP all-sky survey mode

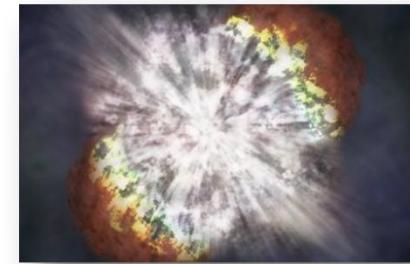
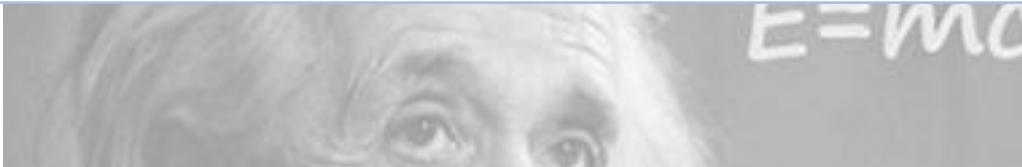


- anti-Sun pointings
- 3 snapshots per orbit, each ~20 min
- 3 orbits (~ 5 hr) cover half sky
- 1 day: ~ 45 snapshots



Main science objectives

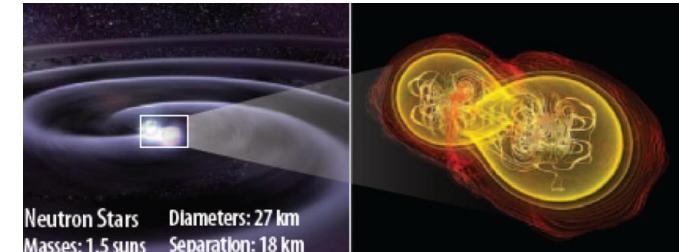
Systematic survey of soft X-ray transients and variability of X-ray sources at an unprecedented combination of high sensitivity and cadence



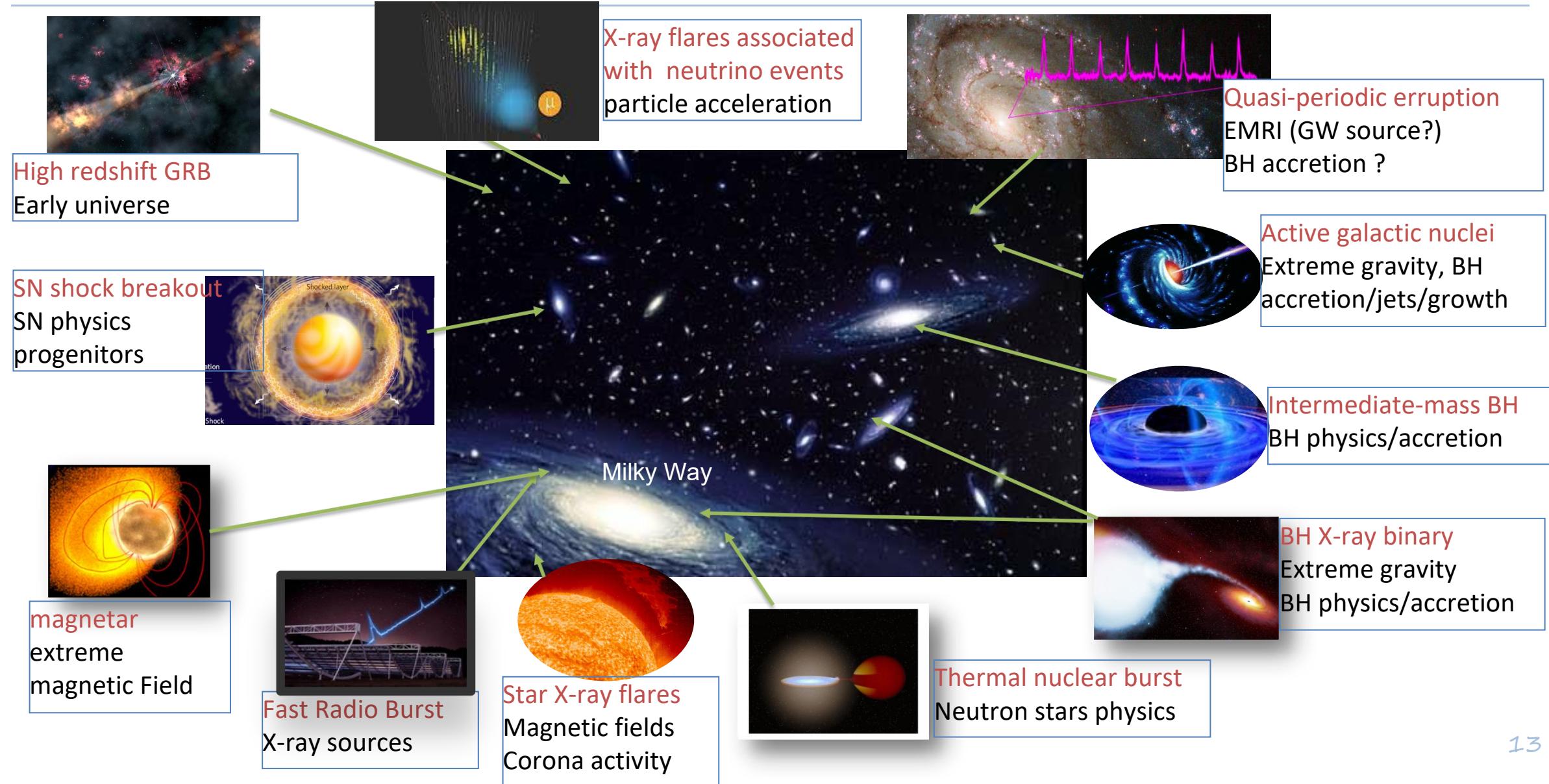
Discover otherwise quiescent **black holes** at almost all astrophysical mass scales and other compact objects by capturing their transient X-ray flares



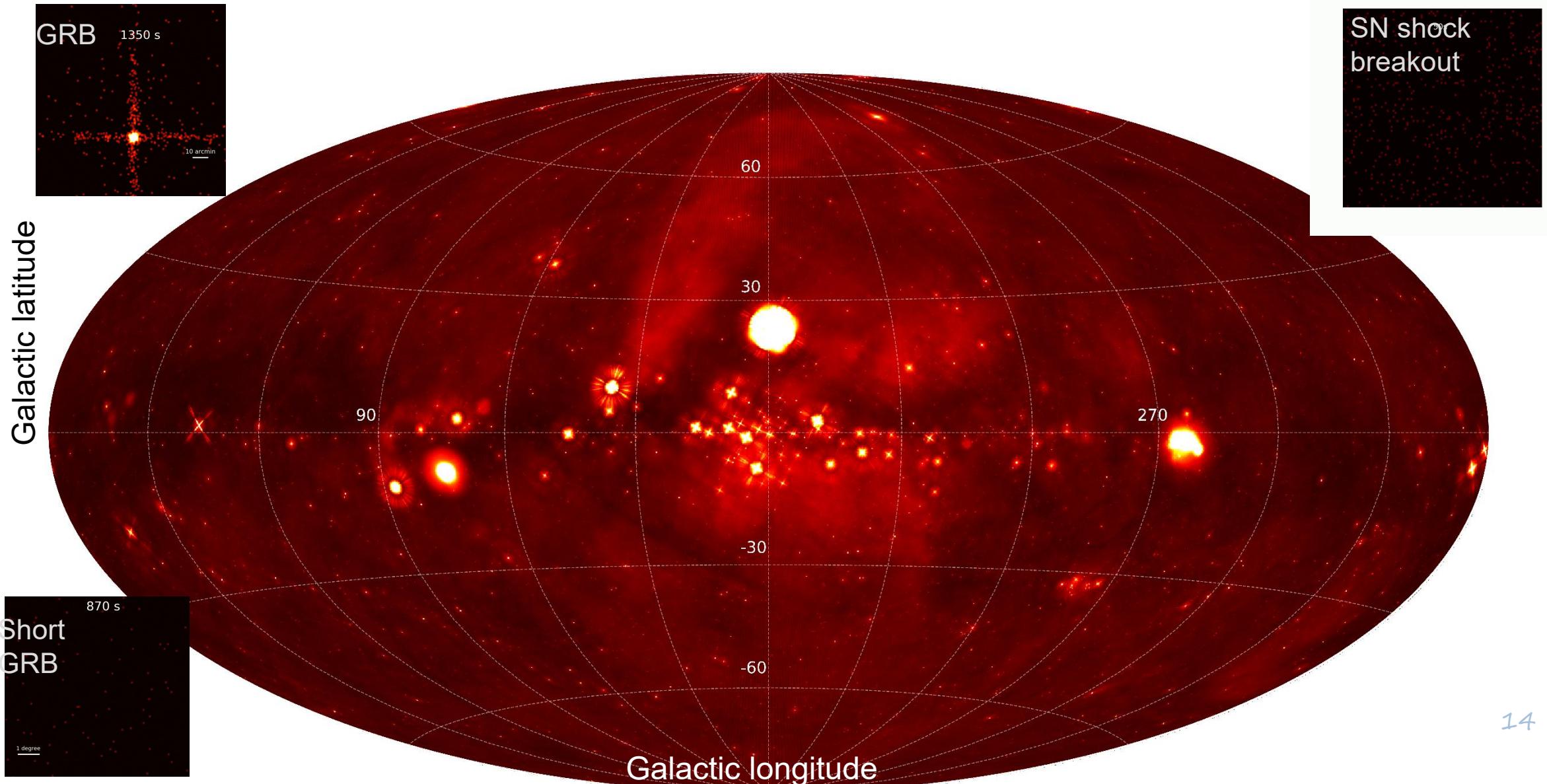
Detect and localise the electromagnetic-wave sources of **gravitational-wave** events by synergy with gravitational-wave detectors



Various classes of high-E transients & variability



Simulated all-sky image & transients in 1-year



Estimated detection rates for selected classes

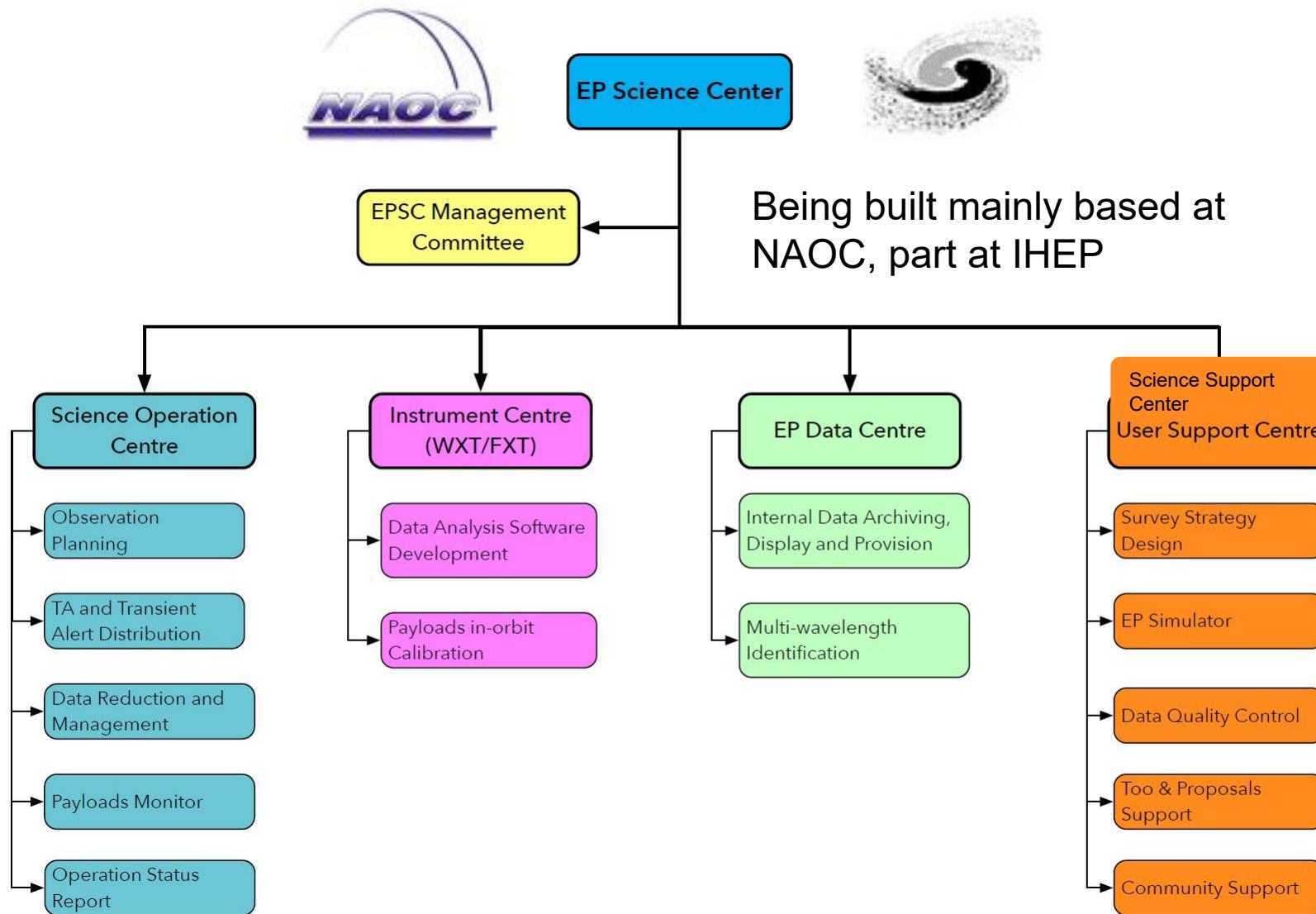
Type of transients	Detections per year	# transients per week
Tidal disruption event (TDE)	10s - 100	EP: >10
TDE with jet	several	Swift: 2.5
Supernova shock breakout	10 – 10s	MAXI: 0.8
Long GRB	10s	challenging to measure redshift !
High-z GRB ($z > 6\text{-}8$)	several	
Short GRB	10	
Low-luminosity GRB	10	
Magnetar	a few	
Stellar flares	a few 10^3	Note: subject to large uncertainties...
AGN monitored daily / weekly	tens / hundreds	

EP consortium

- **Chinese Academy of Sciences**
 - Managed by CAS's National Space Science Centre (NSSC)
 - Institutes: NAOC, IHEP, SITP, MicroSAT, NSSC, others
- **European Space Agency (Mission of Opportunity)**
 - Hardware contribution (mainly FXT Mirror module)
 - Ground station support
 - Science management support
- **Max-Planck-Inst. for extraterrestrial Physics, Germany**
 - Hardware contribution (FXT pn-CCD modules, eROSITA MA FS)
- **CNES, France** (Agreement to be signed)
 - VHF network & support (contribution to EP Science Centre)



EP Science Center



Proposal Tools

■ Proposal submission and review

Apply for EP Time

Notice: please read the [Call for EP proposal](#) first.

[Create a new proposal](#)

I have created or submitted proposal, view my proposal list.

[Back to homepage](#)

Proposal Management

Upload Science Case

Please prepare your science case by modifying template.tex or template.docx. Upload the [PDF](#) document containing your scientific case.

[Click here to download template.tex](#) [Click here to download template.docx](#)

Select file [Upload](#)

[Save Project Overview](#) [Submit Proposal](#)

Science Use Case Submission

Home Mission News Data Center Team Publications Proposal

[Back to Proposal List](#) Status: Draft [View Proposal](#) [Submit Proposal](#)

Project Overview Source List Investigators Peer Review

Proposal Title*:

Abstract*: (No more than 200 Words, this information will be potentially public.)

Proposal Content Filling

Review Proposal List

Total: 1 Awaiting Review: 0

* You can submit and modify your review result before the expiration date.
* A means a perfect proposal, and D indicates a completely unreasonable proposal; please use A for excellent proposals, and assign scores of B to proposals which are overall acceptable, though with room for improvement.
* Please provide your evaluation in relation to other EP proposals as much as possible. The novelty, the expected science return, and the timely publication of the respective programs will be highly valued by the observatory.

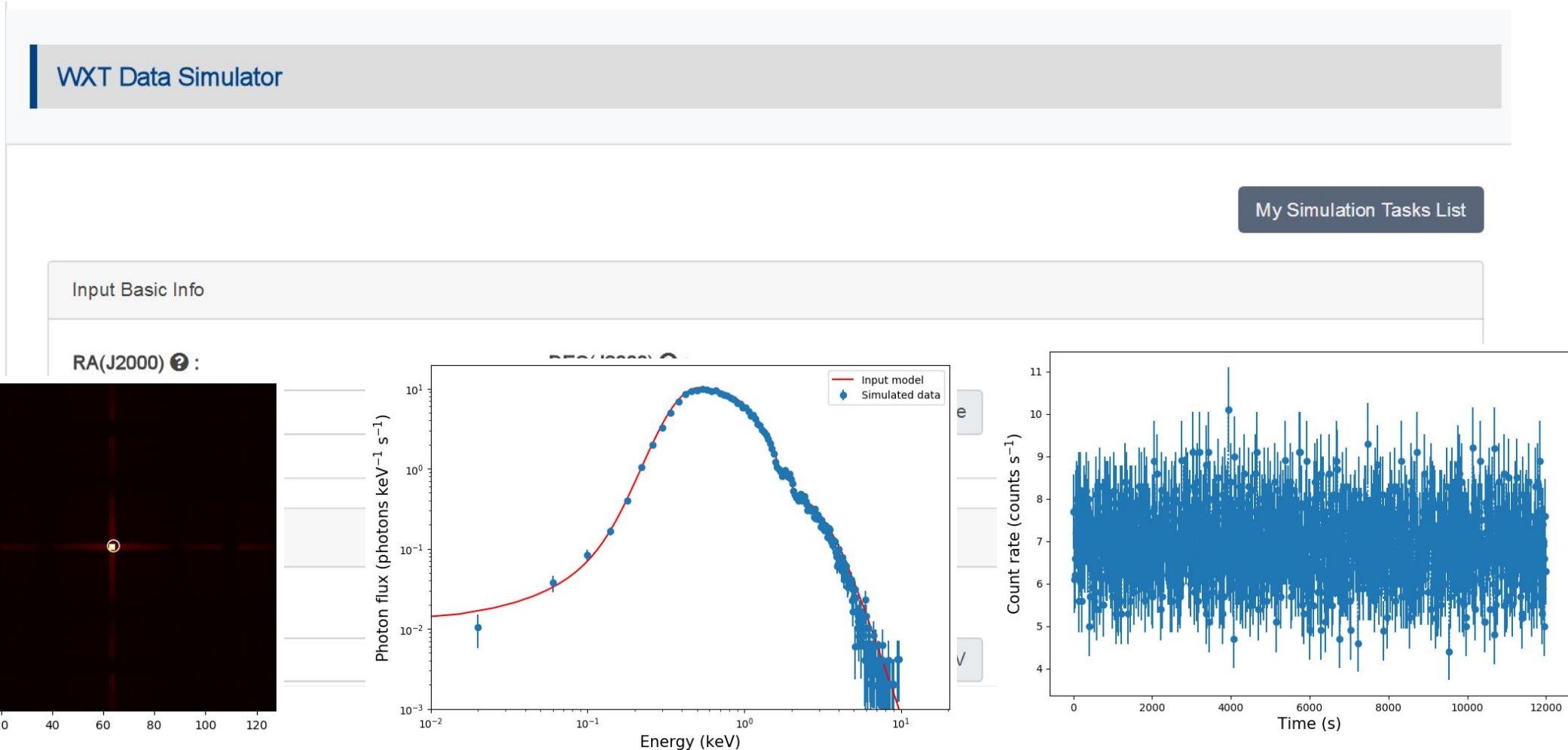
NO	Expiration(UTC+8)	PI-Name	Request(hours)	Status	Technical Review	Proposal	Peer Review
SQB-Test Season-0001	2022-05-29 00:00:00	Yunfei XU	0.2	Reviewed	View	View	Modify

[Previous Page](#) 1 [Next Page](#)

Proposal Review Management

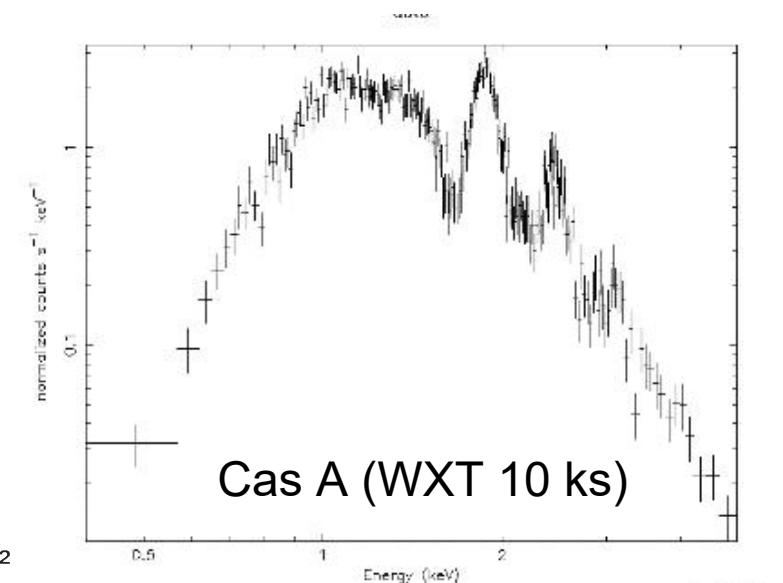
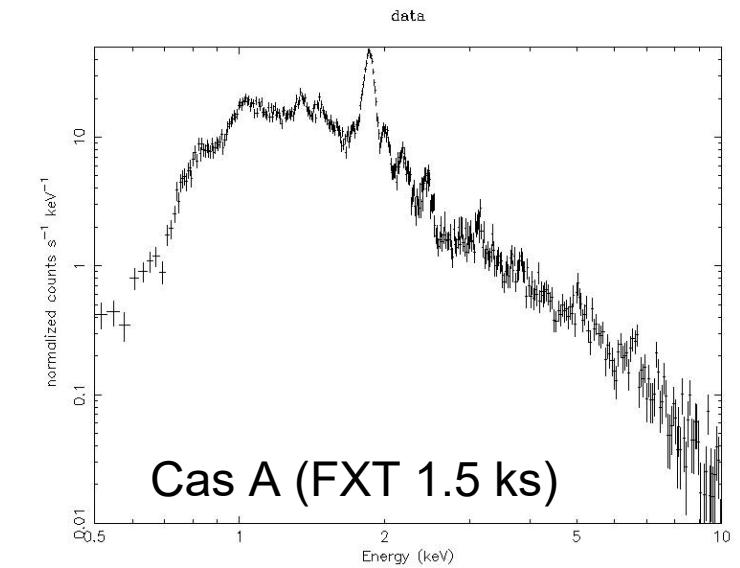
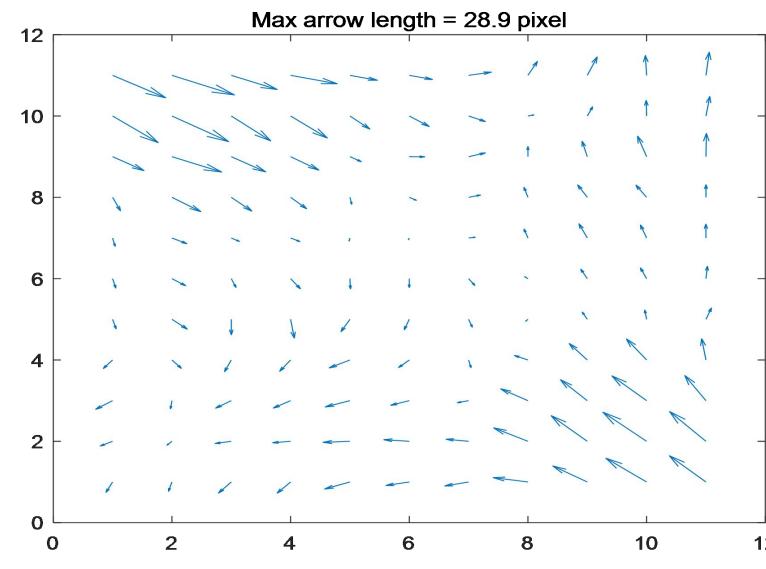
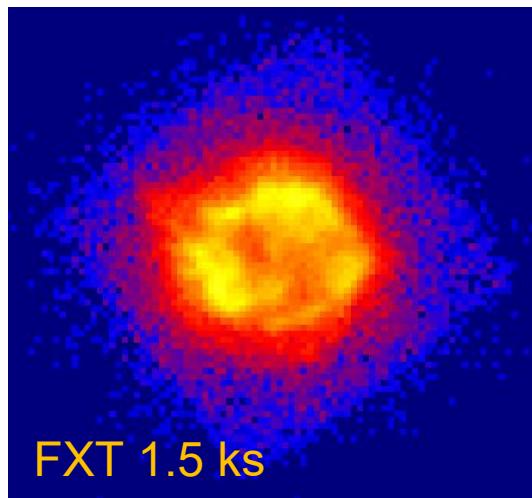
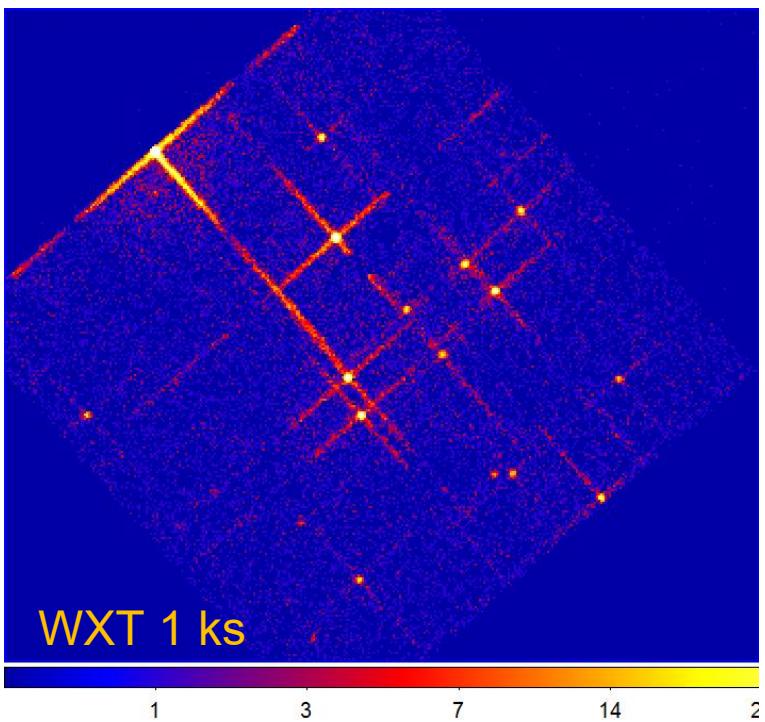
WXT online simulator

- Simple and quick



Data reduction software

- Define data products
- Build CALDB
- Develop and test software
- HEASARC framework



Transient database

The EP team has just performed a simulation for a one-day observation with the Einstein Probe WXT Transients satellite. The simulation mimics the equipment's capability to detect short gamma-ray bursts (SGRBs), high-luminosity long gamma-ray bursts (LL-LGRBs), low-luminosity long gamma-ray bursts (HZ-LGRBs), supernova shock breakout (SBO), and transients (TDE).

The simulation data can be visualized and browsed using the EP/WXT Transients visualization interface.

Observation Details

- Observation mode:** Pointing observation in WXT Sky Survey mode
- Observation Duration:** 2022.11-2023.10
- Number of observations:** 16329
- Data Volume:** 500GB
- Simulation time:** 2.5 days under 55(64) cores

Input Samples

- Known source:**
 - ROSAT Point Source:** (1rxs + 2rxs)
 - MAXI Source:** a total of 407, the number of sources with a flux density greater than 10 erg/cm²s⁻¹ (arcmin)² is 191
- Transient:** TDE, SGRB, HL-LGRB, LL-LGRB, HZ-LGRB, SN SBO, MAXI Known Sources
- Diffuse Radiation:** ROSAT diffuse radiation (0.09-0.2 keV)

Exposure time

Base image layer
DSS colored
Color map:
native Reverse

Overlay layers
 TDE Reticle HEALPix grid

Tools
Export view as PNG

Source List **Explorer**

Choose Observation Type: two pointing observations

TDE	SGRBs	HL-LGRBs	LL-LGRBs	HZ-GRBs
-----	-------	----------	----------	---------

J2000d 96.1901025 +50.2272813

Source List **Explorer**

Choose Observation Type: two pointing observations per orbit

TDE	SGRBs	HL-LGRBs	LL-LGRBs	HZ-GRBs	SN SBO	MAXI Known Sources
-----	-------	----------	----------	---------	--------	--------------------

Lists of Transient: SGRB (two pointing observations per orbit) All 16 Rows

ID	Source Name	RA	Dec	Flux	Absflux	Cmosnum	SNR	OBS Number	Show Details
1	MJ000330-250202	0.88	-25.03	3.17e-9 erg·cm ⁻² ·s ⁻¹	8.92e-10 erg·cm ⁻² ·s ⁻¹	24	43.26	1	<button>Hide Details</button>
2	MJ010604-055655	16.52	-5.95	2.16e-9 erg·cm ⁻² ·s ⁻¹	3.62e-10 erg·cm ⁻² ·s ⁻¹	1	21.17	1	<button>Show Details</button>
4	MJ012018-400151	20.08	-40.03	1.32e-9 erg·cm ⁻² ·s ⁻¹	1.29e-10 erg·cm ⁻² ·s ⁻¹	8	14.95	1	<button>Show Details</button>
8	MJ021602+714922	34.01	71.82	7.09e-9 erg·cm ⁻² ·s ⁻¹	6.14e-10 erg·cm ⁻² ·s ⁻¹	1	28.70	6	<button>Show Details</button>
10	MJ032433-032642	51.14	-3.45	6.61e-9 erg·cm ⁻² ·s ⁻¹	3.84e-10 erg·cm ⁻² ·s ⁻¹	35	21.92	4	<button>Show Details</button>
11	MJ043247+245909	68.20	24.99	5.24e-9 erg·cm ⁻² ·s ⁻¹	4.07e-10 erg·cm ⁻² ·s ⁻¹	37	16.13	1	<button>Show Details</button>
12	MJ044440+495403	71.17	49.90	1.57e-9 erg·cm ⁻² ·s ⁻¹	2.80e-10 erg·cm ⁻² ·s ⁻¹	41	2.70	59	<button>Show Details</button>
14	MJ050139-692519	75.41	-69.42	1.23e-9 erg·cm ⁻² ·s ⁻¹	3.71e-11 erg·cm ⁻² ·s ⁻¹	1	5.09	1	<button>Show Details</button>
16	MJ054819+492100	87.08	49.35	1.45e-9 erg·cm ⁻² ·s ⁻¹	1.33e-10 erg·cm ⁻² ·s ⁻¹	8	8.81	1	<button>Show Details</button>
21	MJ074316+142638	115.82	14.44	7.27e-9 erg·cm ⁻² ·s ⁻¹	1.14e-10 erg·cm ⁻² ·s ⁻¹	37	11.09	20	<button>Show Details</button>

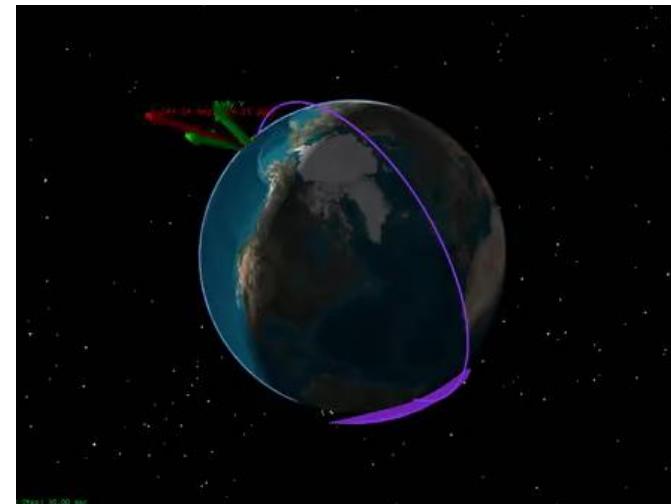
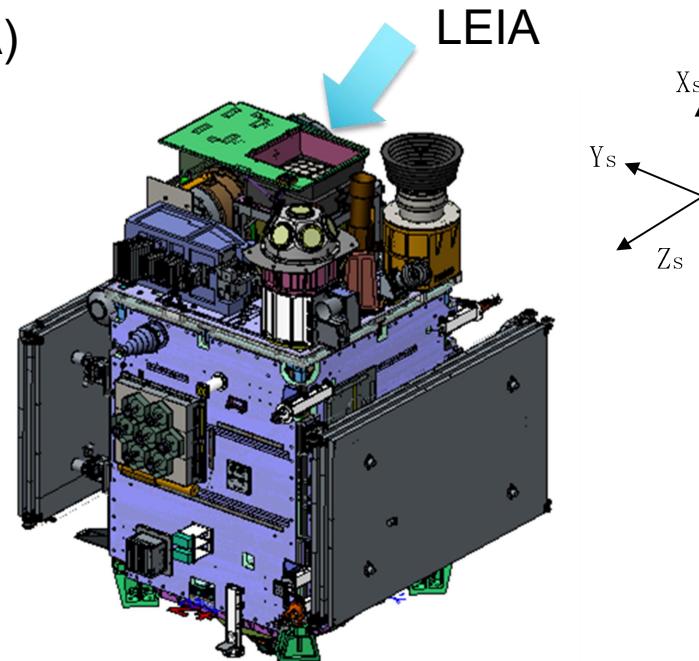
Transient Image **Light Curve** **Spectrum** **Spectrum First** **Spectrum Second** **Spectrum Stack Original**

Data policy

- Alert information of transients will be released immediately
 - Source position, flux, time, etc.
- Data will be made public after proprietary periods
 - Survey and follow-up observations: one year
 - ToOs: 6 months
- EP science team: a single joint team of all partners
 - CAS-ESA-MPE: 80% - 10% -10%
 - Joint exploitation of EP data with projects led by the parties in above proportion
 - Science management committee composed of members from all three parties

WXT pathfinder

Lobster Eye Imager for Astronomy (LEIA)

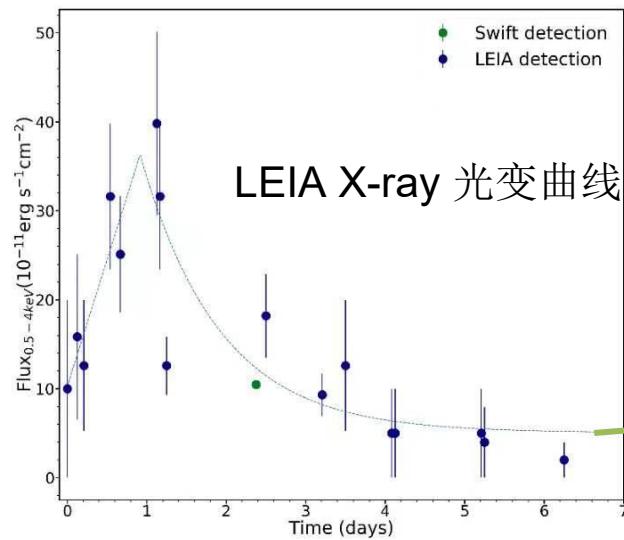


Successfully launched 2022 July 27, @Jiuquan

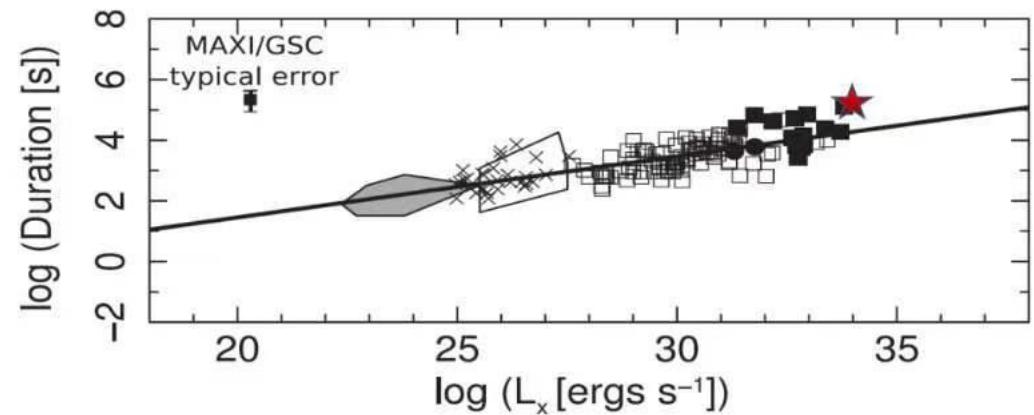
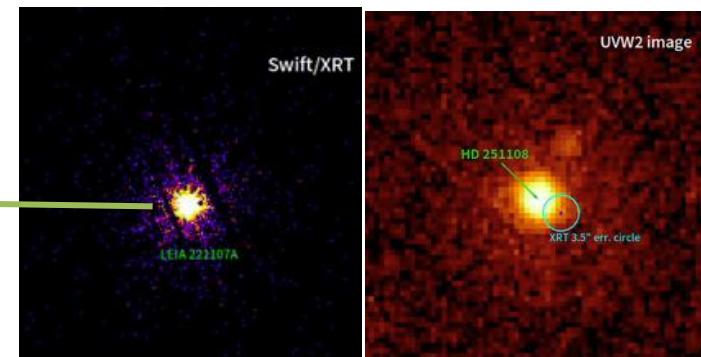
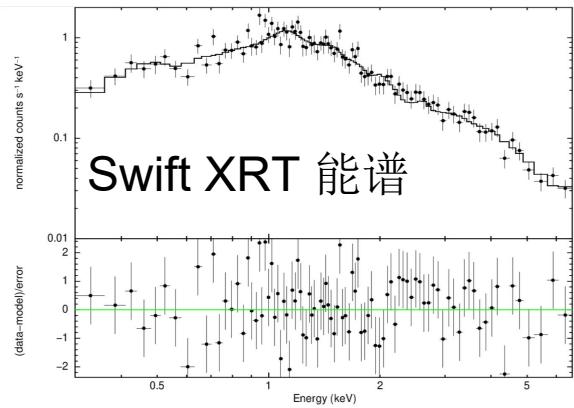
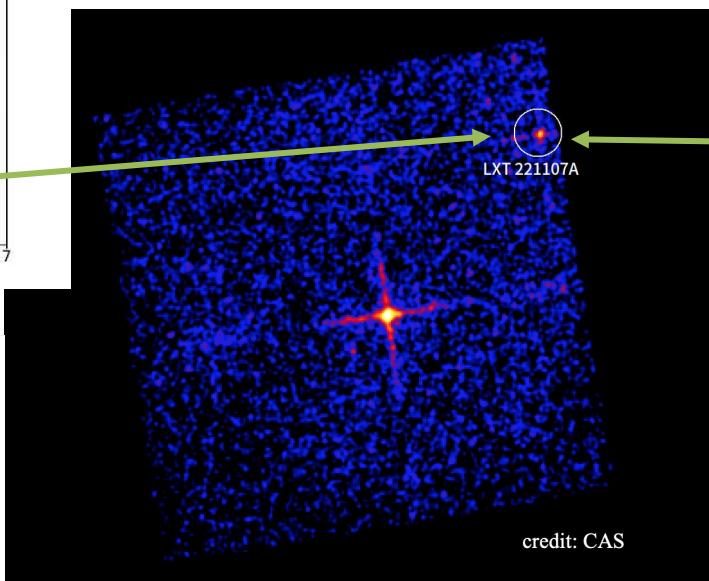
中科院力学所力箭 1 号

LEIA first results: stellar flares

LXT 221107A 超级恒星耀发

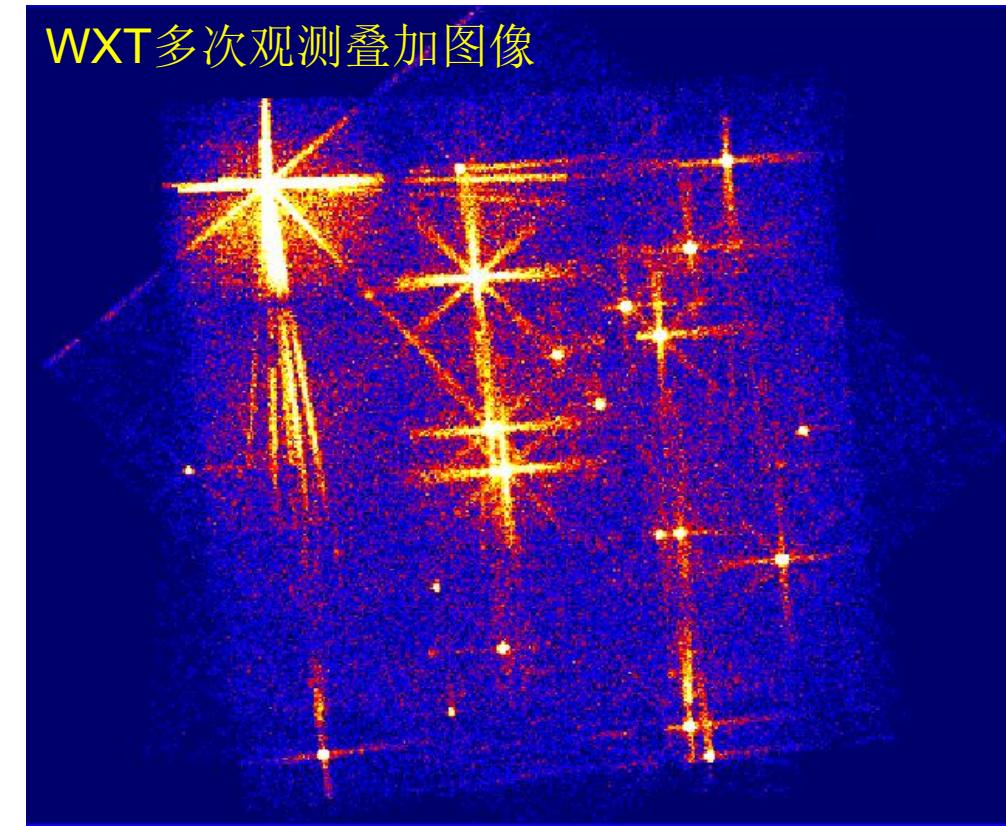
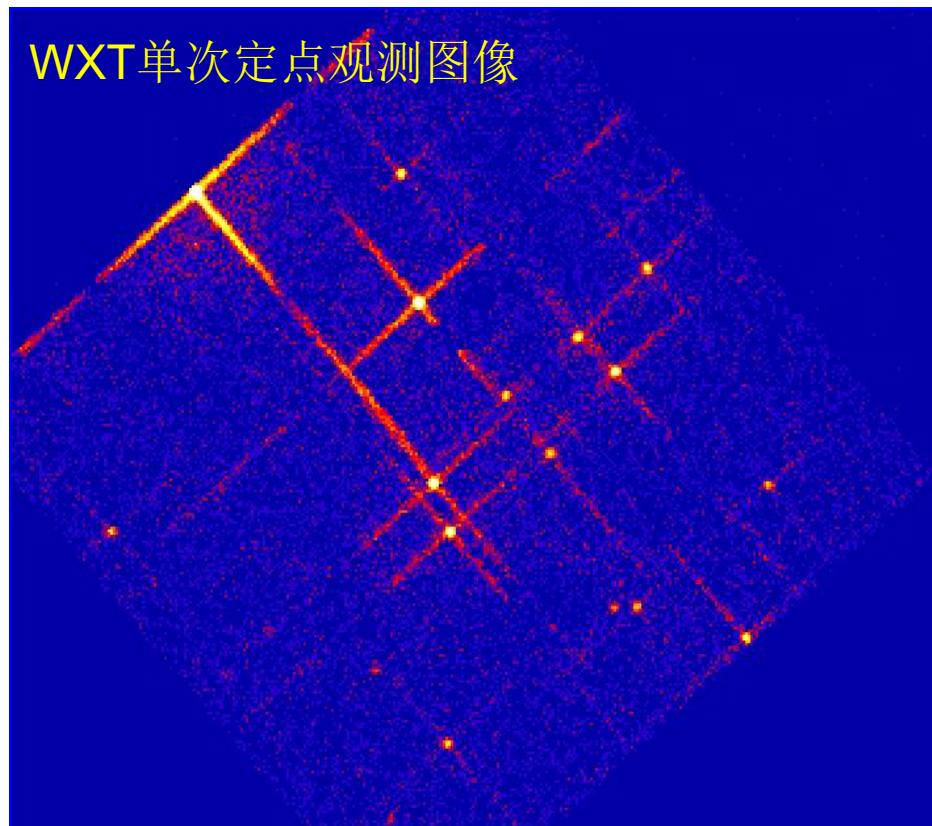


LXT221107A 恒星X-ray超级耀发



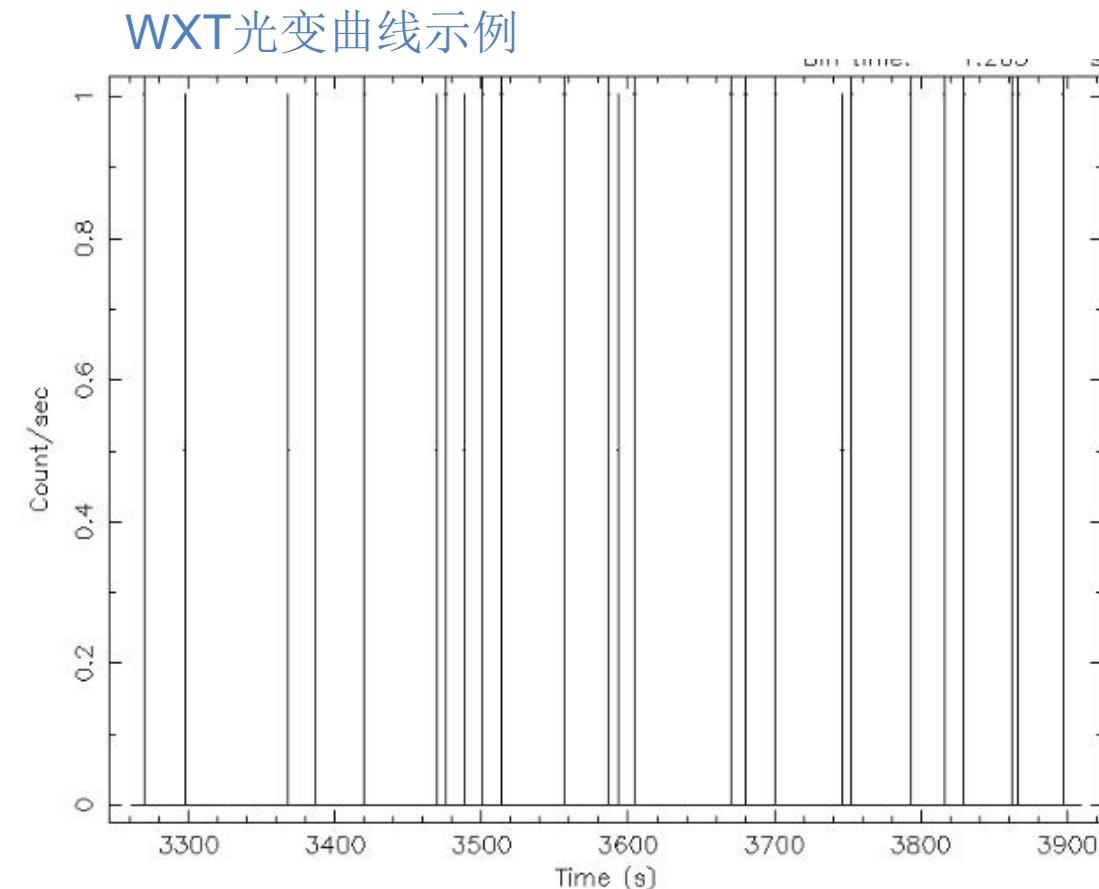
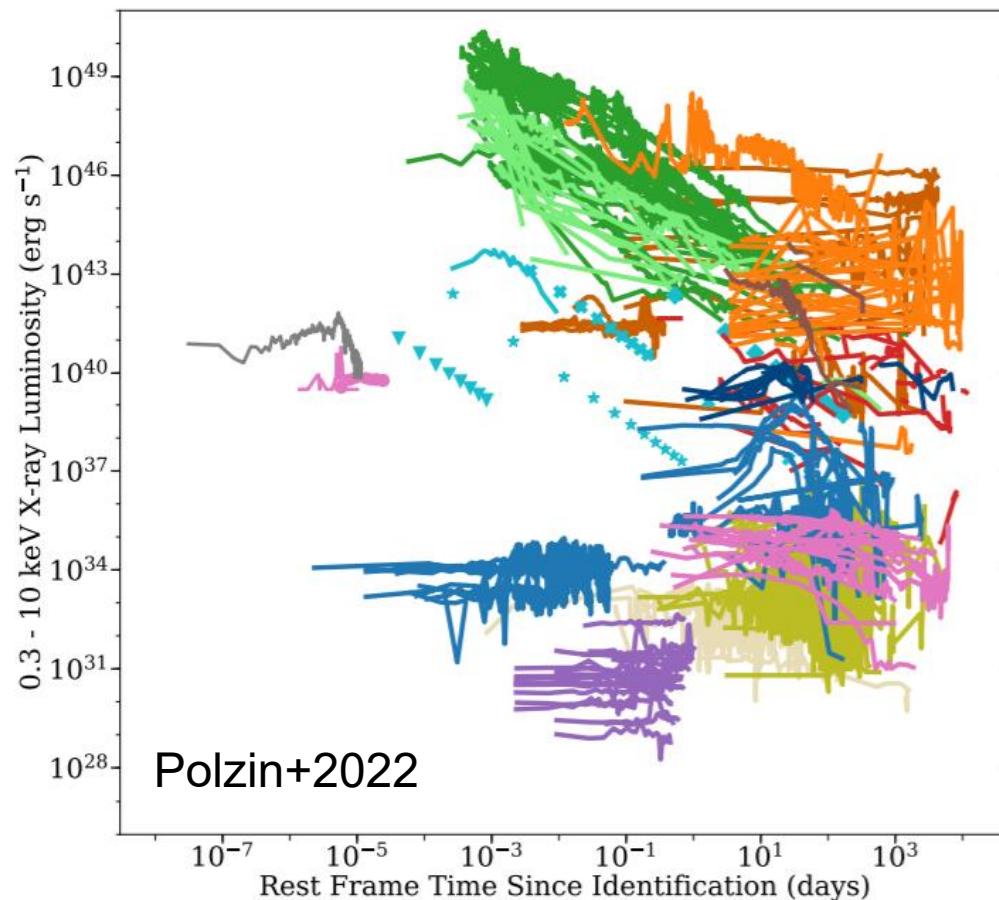
源探测

- 含有十字臂结构图像的源探测方法
- 多次叠加图像的源探测方法
- 依据光子列表的源探测方法



源分类

- X射线暂现源的类别众多，在探测到之后如何根据WXT的数据以及其他多波段设备的数据对源进行快速、准确的分类？
- 如何有效地确定已知类别的源的同时发现未知的新型暂现天体？



EP项目招聘岗位



EP科学中心项目支持科学家

职责：

- (1) 参与EP科学中心的日常运行工作，包括担任值班科学家或观测助手、开发和维护相关软件、处理各类运行数据、观测任务、用户信息等工作。
- (2) 基于EP和EP探路者LEIA载荷的数据，结合其他地面和空间望远镜的协同/后随观测，开展相关的X射线天文和高能天体物理的观测和理论研究。
- (3) 负责人交办的其他工作

要求：

具有良好的科学素养和研究能力，具有物理学或天文学博士学位。从事高能天体物理方向研究（具有X射线天文研究经历优先）。

EP网站和服务器运维工程师

职责：

- (1) 负责EP网站的日常维护和需求开发及网站Bug处理；
- (2) 根据需求完成EP网站信息的更新以及信息资源的整合；
- (3) 配合完成EP相关软件的升级、更新和维护等工作；
- (4) 负责计算机网络、服务器安全运行和数据备份，网络对外接口和系统安全管理等工作；
- (5) 负责人交办的其他工作

要求：

本科（含）以上学历，具有实际软件工程开发经验；具有物理或天文相关方向研究经历优先；精通C/C++程序开发；熟悉常用脚本语言和Linux系统的使用；熟悉软件工程管理。

Summary

- X-ray sky is rich in various classes of transients and variables
- Future of monitoring dynamic X-ray sky is promising, enabled by Lobster-eye MPO technology
- Einstein Probe will discover/characterise a large number of faint X-ray transients, and monitor source variability
- Challenges to source detection and classification

liuyuan@bao.ac.cn

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

<https://www.bilibili.com/video/BV1mf4y1b7YJ>