Einstein Probe

----- exploring the dynamic x-ray universe

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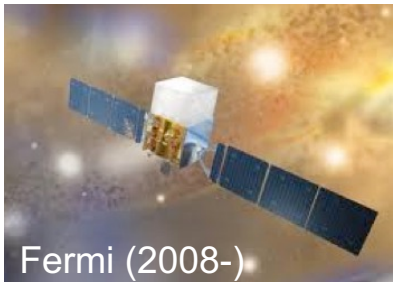
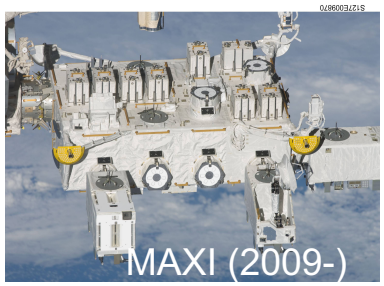
On behalf of
the EP consortium

Scientific drivers for future X-ray all-sky monitors

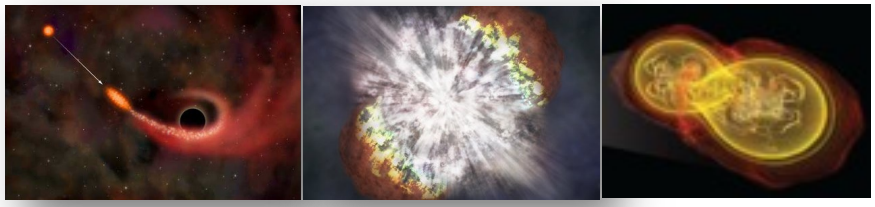
- The Universe is rich in high-energy transients and variables

INTEGRAL (2002-)





- New transients continue to be discovered, and need observational characterisation in large samples
- exciting examples:
  - Tidal disruption events
  - Supernova shock breakouts
  - High-z GRBs
  - EM sources of gravitational wave events
- Expected/unexpected new types !



distant and faint

Really need next generation of ASM

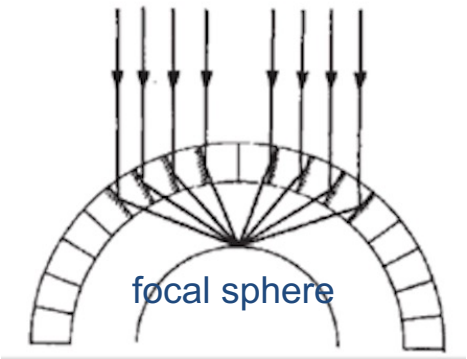
MPO: Wide-field X-ray focusing technology

Lobster-eye Micro-Pore Optics (MPO): enabling true focusing imaging for wide-field X-ray instruments

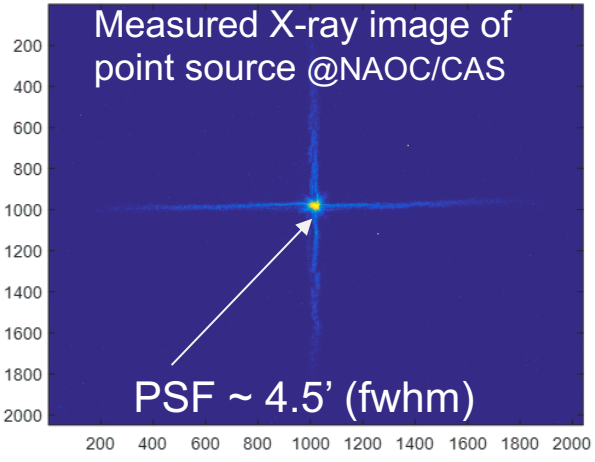
- Wide FoV: > 10^3 sq.deg
- Moderate angular resolution: arc-minutes
- Moderate sensitivity: < ~ 1mCrab @1 ksec

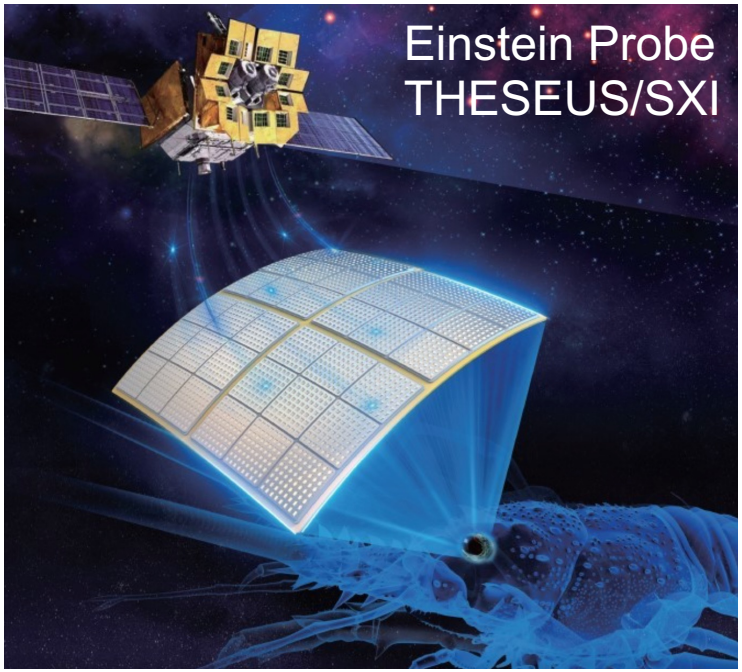
significant improvement upon current instruments (non-focusing)

see P. O'Brien's talk



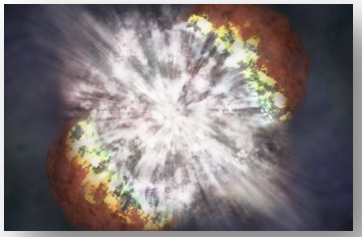
Lobster-eye MPO



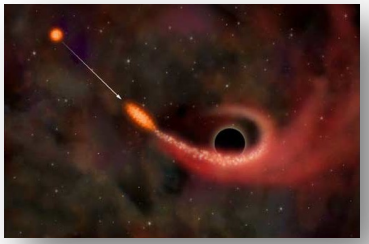


Einstein Probe (EP) : main science goals

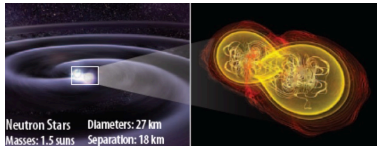
Carry out systematic survey of soft X-ray transients and variability of X-ray sources at an unprecedented combination of high sensitivity and cadence



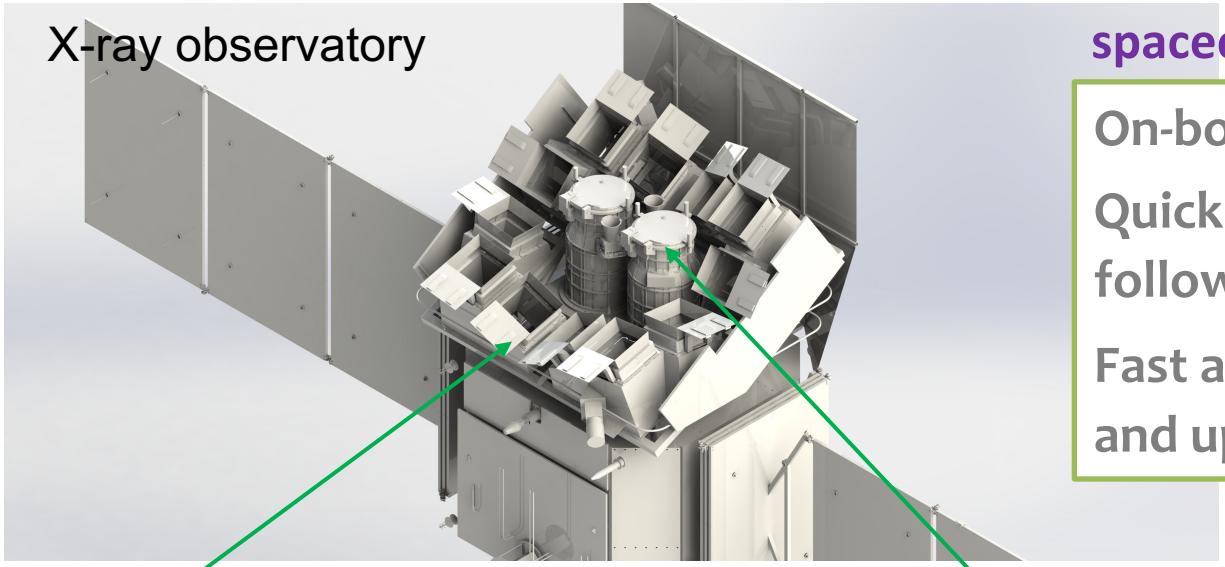
Discover otherwise quiescent Black holes at almost all astrophysical mass scales and other compact objects by capturing their transient flares



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



EP payloads and features



spacecraft

- On-board data processing
- Quick slew & autonomous follow-up
- Fast alert data downlink and uplink (ToO)

WXT (12 modules)

Wide-field X-ray Telescope

- lobster-eye MPO
- FoV: 3600 sq deg (1.1 sr)
- band: 0.5 – 4 keV
- resolution: ~ 5' (FWHM)
- sensitivity: 10s better than ASM now

FXT (2 modules)

Follow-up X-ray Telescope

- Wolter-1 telescope
- FoV: ~ 1 deg
- band: 0.3-10keV
- eff. area: 300cm² @1keV (1 unit)
- resolution: 30" (HPD)

EP consortium

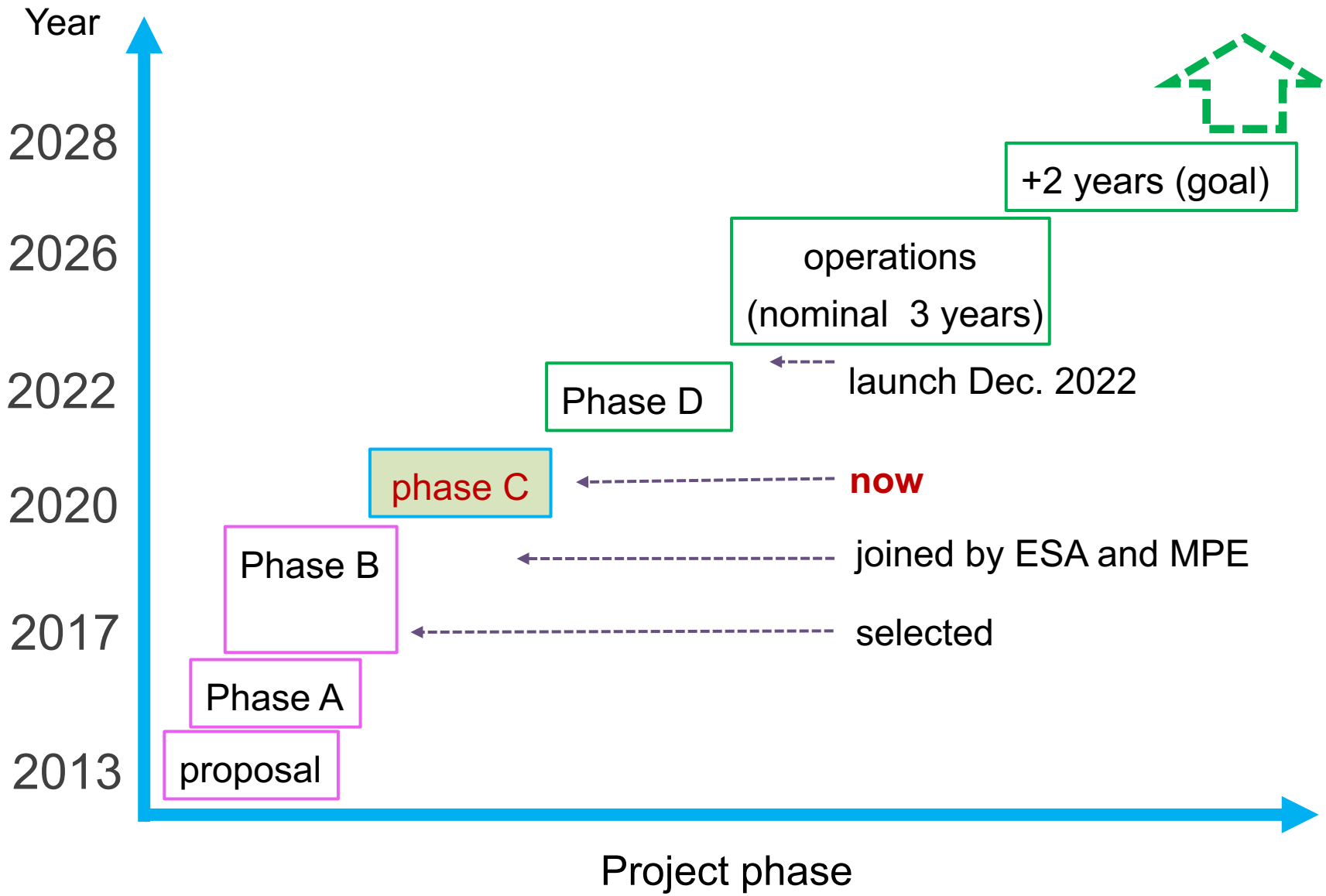
- Chinese Academy of Sciences (CAS)
  - Managed by CAS's National Space Science Centre (NSSC)
  - Institutes: NAOC, IHEP, SITP, MicroSAT, NSSC

- European Space Agency (Mission of Opportunity)
  - Hardware contribution (mainly FXT)
  - Ground station support
  - Science management support

- Max-Planck-Inst. for extraterrestrial Physics
  - Hardware contribution (FXT)

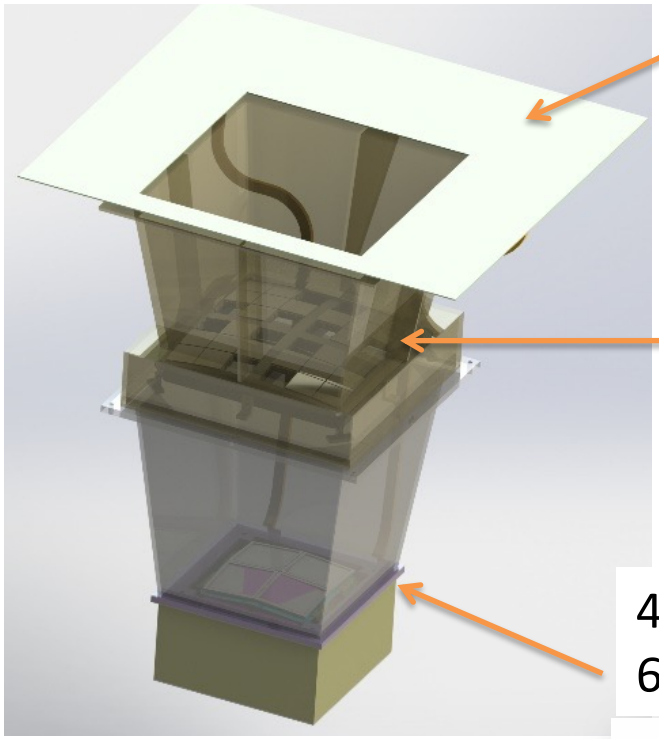
- CNES/CEA (collaboration in discussion)
  - VHF network & support/tools (contribution to EP Science Centre)

Project timeline



Wide-field X-ray Telescope (WXT)

One of 12 WXT modules

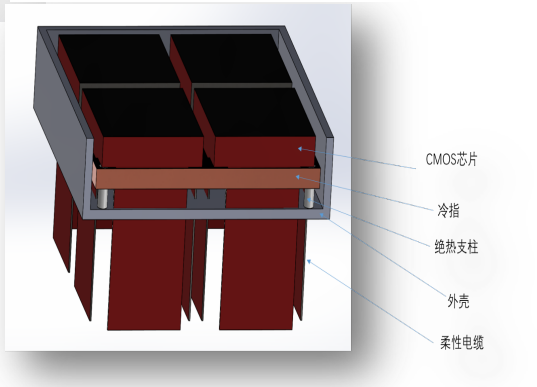


Focal length: 375mm

eff. area: ~3 cm^2 @1keV (PSF centre)

36 MPO plates

4 BI CMOS
6cm x 6cm each

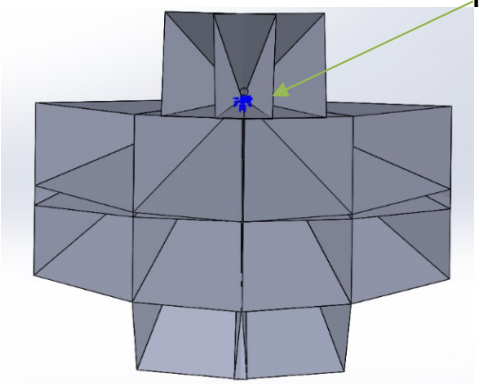


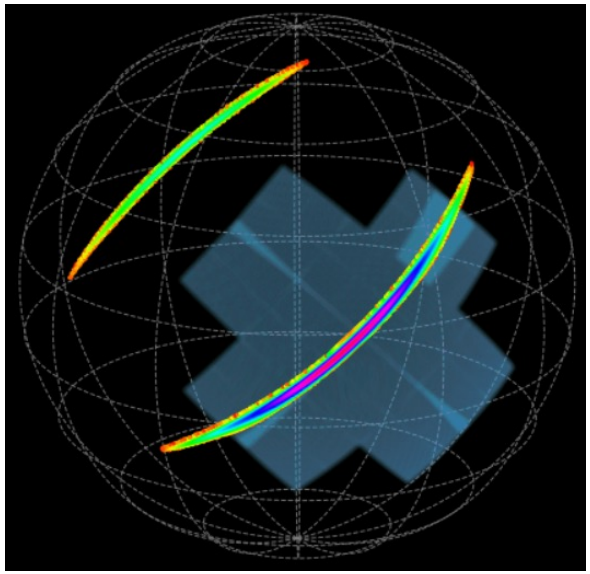
- Development
  - CAS (SITP+NAOC)
  - MPO: NNVT
  - CMOS
- Testing/calibration
  - CAS (NAOC+IHEP)
  - ESA (+ MPE)

The largest-format detector for focusing X-ray telescopes ever (total 1728 cm^2)

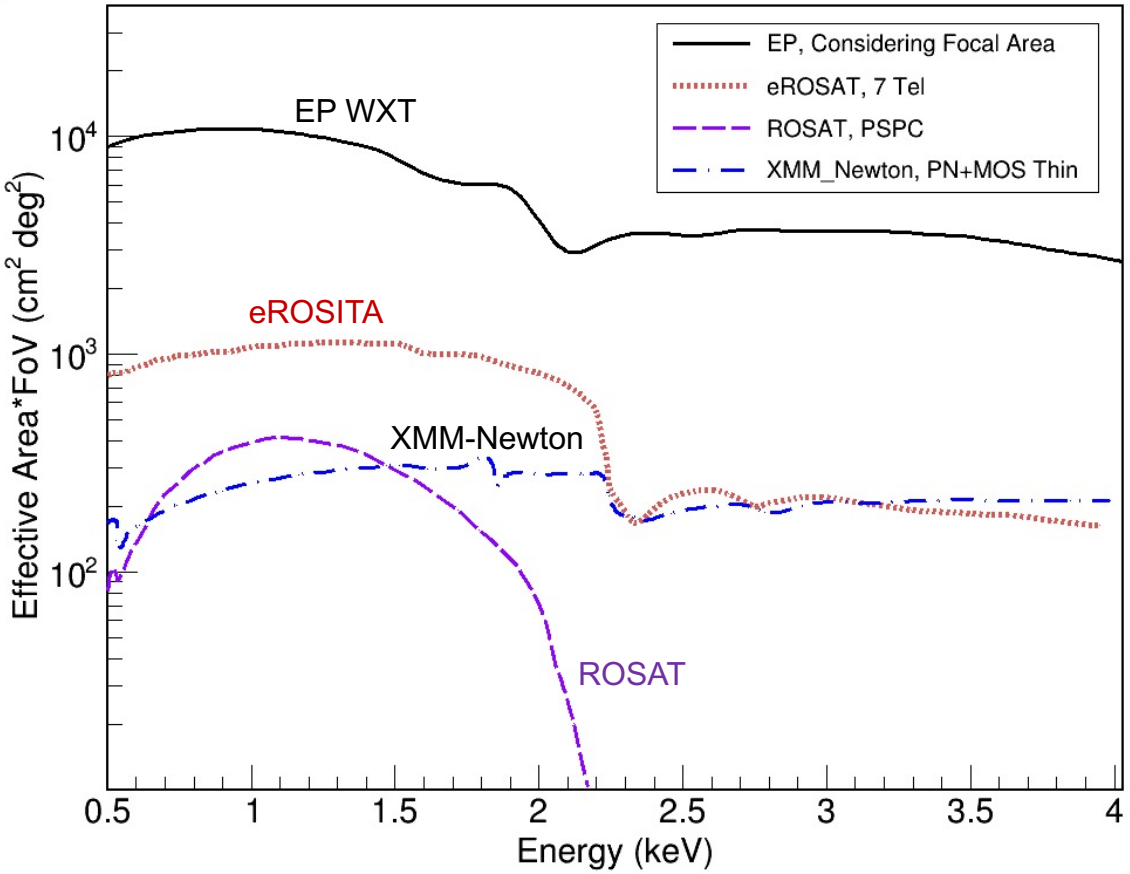
WXT FoV and Grasp

WXT FoV (1.1sr)





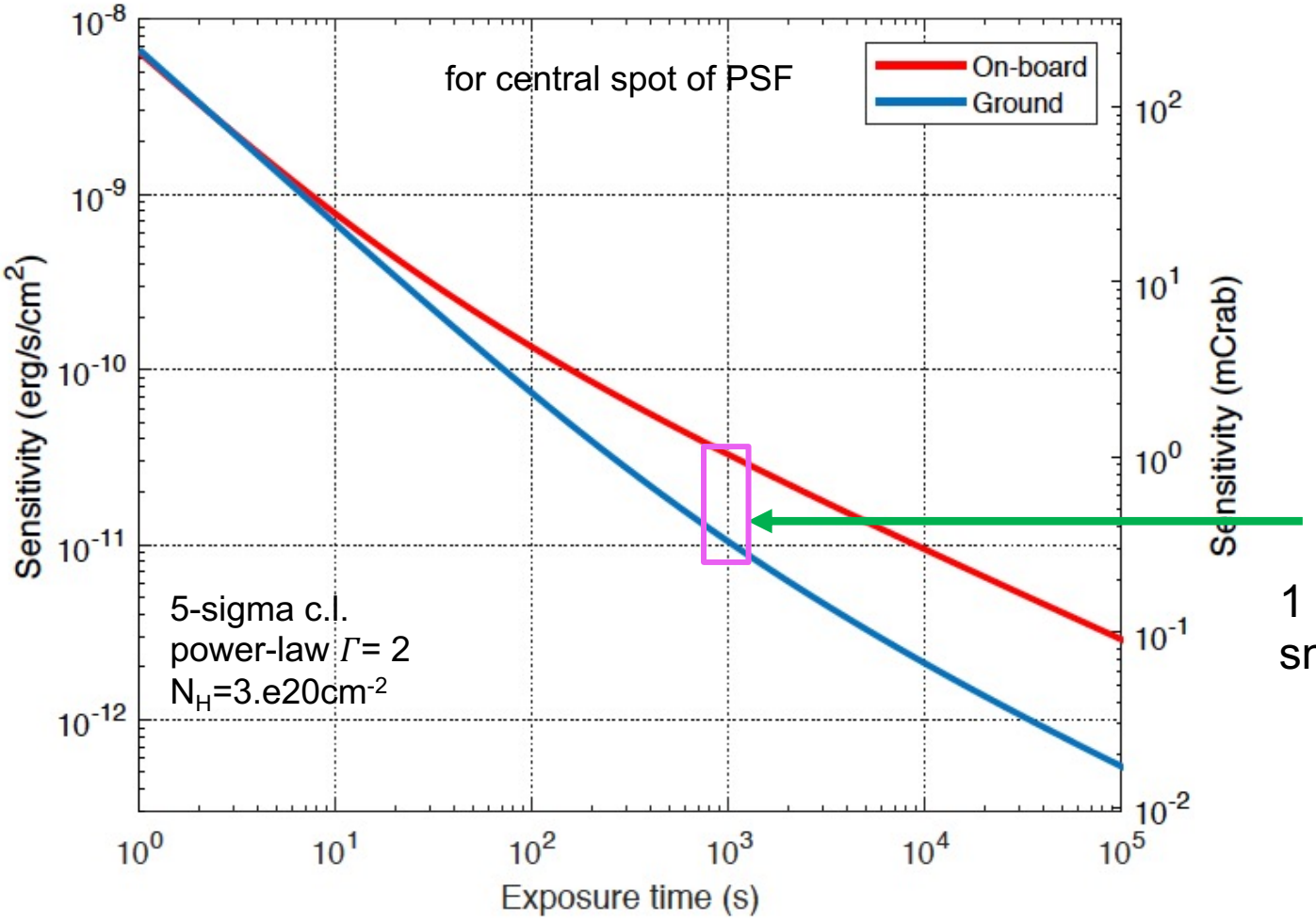
Grasp



Zhao D. et al. 2017

Compared with typical GW source locus

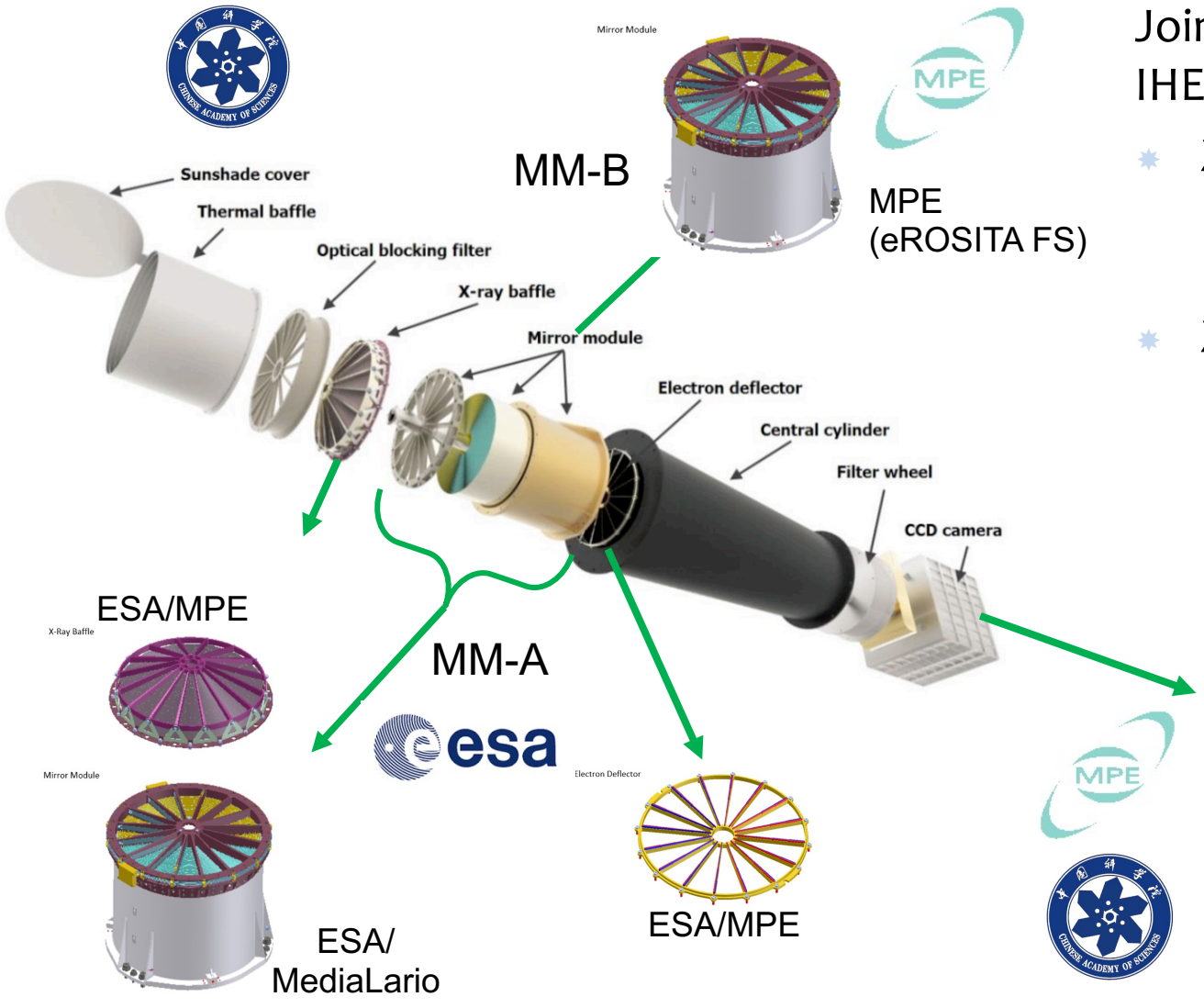
Simulated WXT sensitivity (goal)



1 survey snapshot

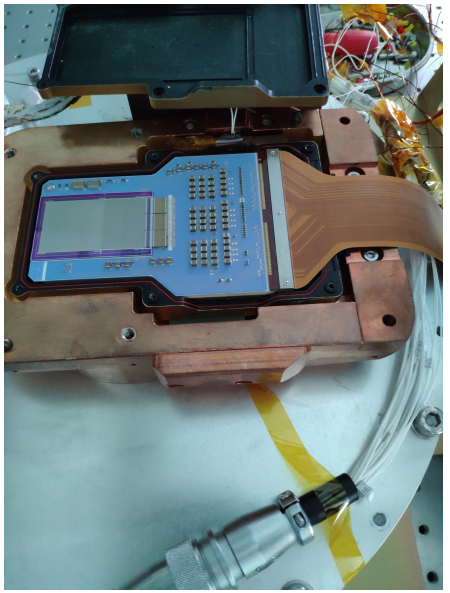
tens times better than current X-ray ASM (e.g. MAXI, Swift)

Follow-up X-ray Telescope (FXT)



Joint developed by IHEP/CAS, ESA and MPE

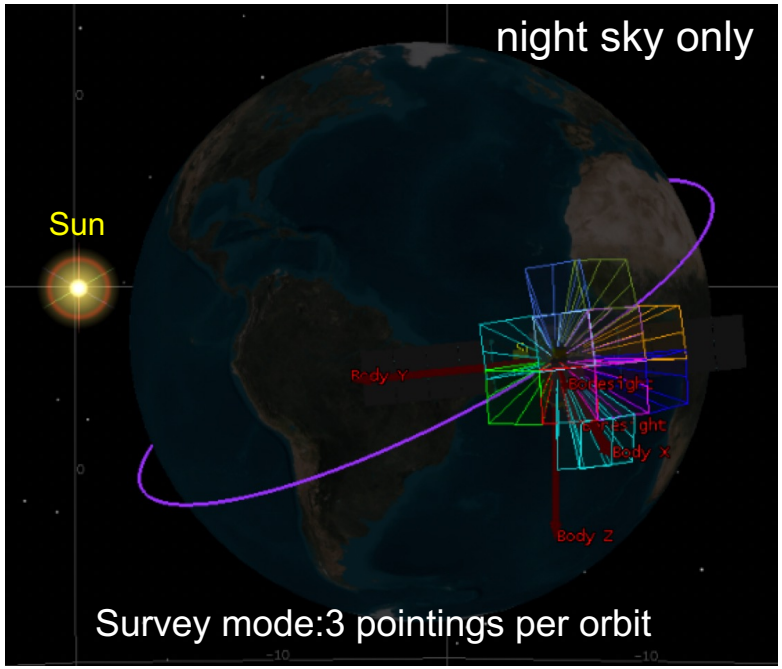
- X-ray optic systems
  - ESA + MPE
  - eROSITA design
- X-ray cameras
  - PN-CCD module (MPE)



Mission profile

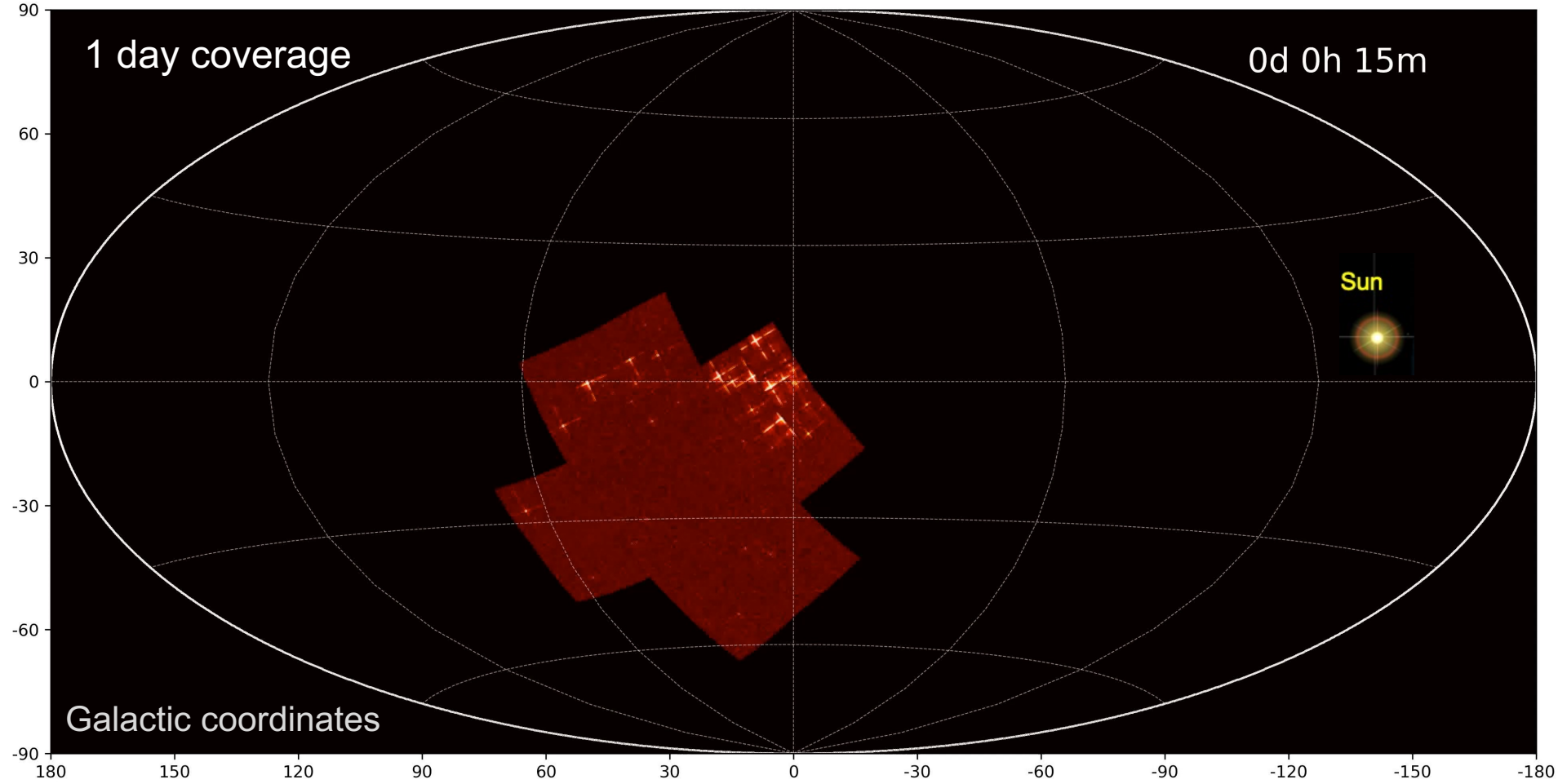
- Orbit: ~ 600 km (96min), i =29 deg
- Observation modes
  - Survey: 3 snapshots per orbit in night-sky, each ~ 1 ksec
  - Autonomous X-ray follow-up

    spacecraft slew-time 3 - 5 min
  - ToO
- Alert data rapid downlink
  - Beidou system (China)
  - VHF (CNES)
  - Alert information will be publicly released quickly
- ToO command uplink
  - Normal (S-band): < 1 day
  - Time critical (Beidou): < 10 min



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

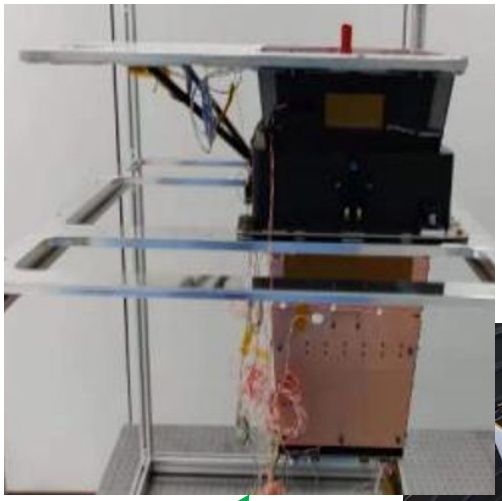
WXT survey coveage footprints



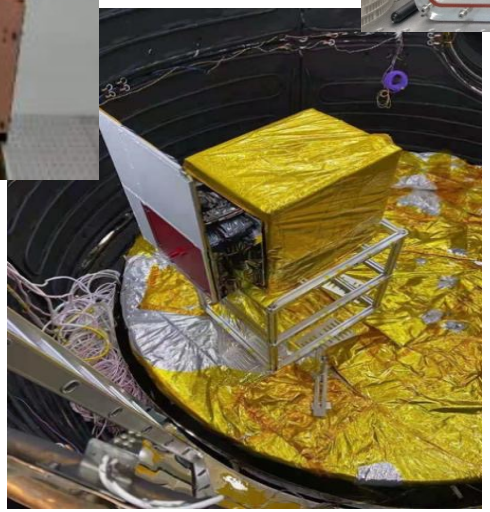
- In 3 orbits (~ 5hr) WXT covers most of the night sky (can be disrupted)
- Cover the whole sky in half year
- Good synergy with other M-W & M-M facilities (LSST/SKA/Swift/SVOM/LIGO/...)

WXT status

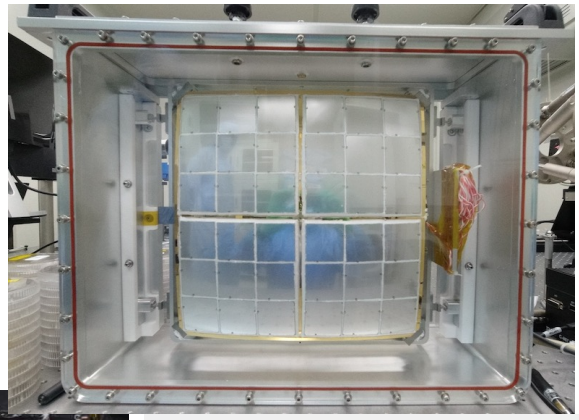
- 3 qualification models (QM) of mirror modules built and being tested
  - QM3 to be tested at Panter next week
- 2 qualification models of complete WXT modules built, and tests and calibration being/to be carried out



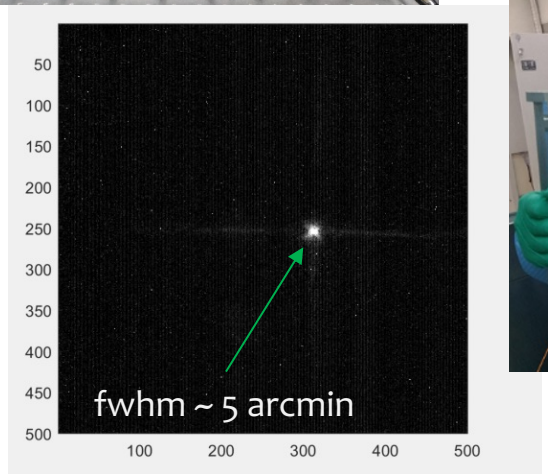
WXT QM

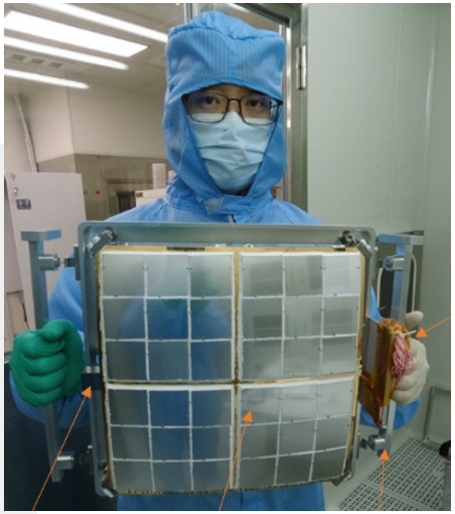


In thermal test
@SITP/CAS



mirror module QM
@NAOC/CAS

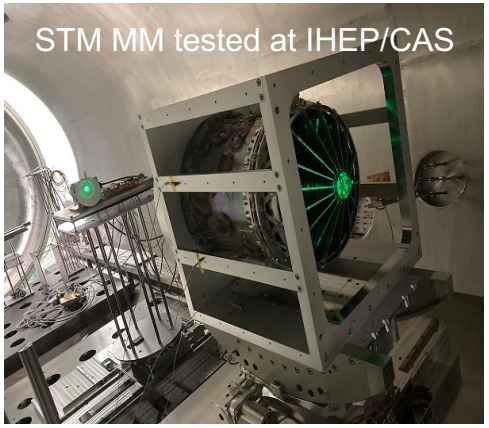


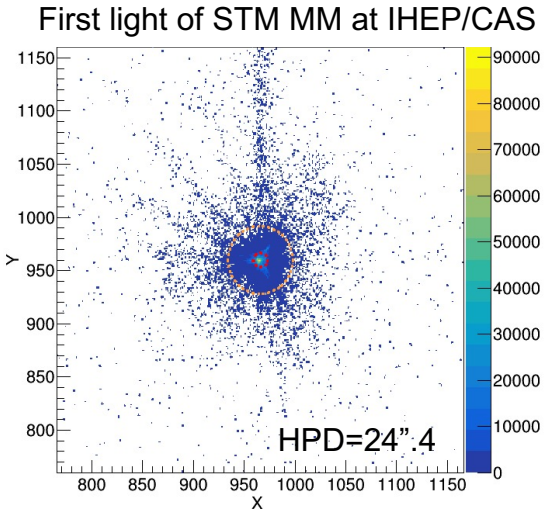


FXT Status

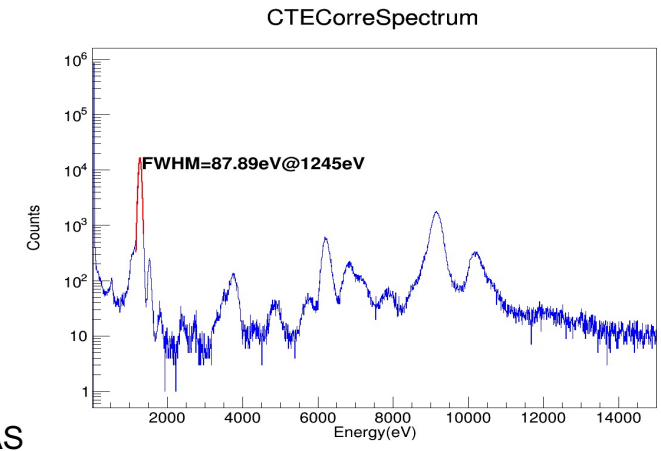
- Structural-thermal model (STM) of mirror module (provided by ESA/Media-Lario) has been tested at Panter and is being tested at CAS/IHEP
- An X-ray camera QM built at CAS/IHEP using detector module provided by MPE

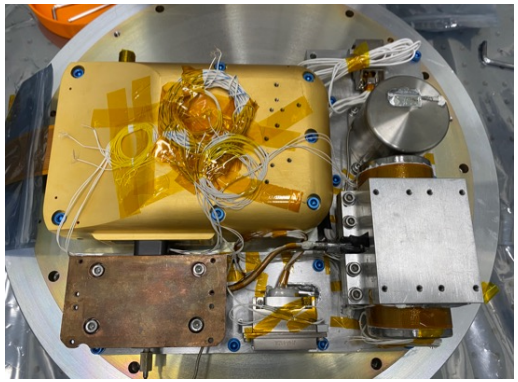
STM MM (ESA/MediaLario)





Camera assembling at IHEP/CAS

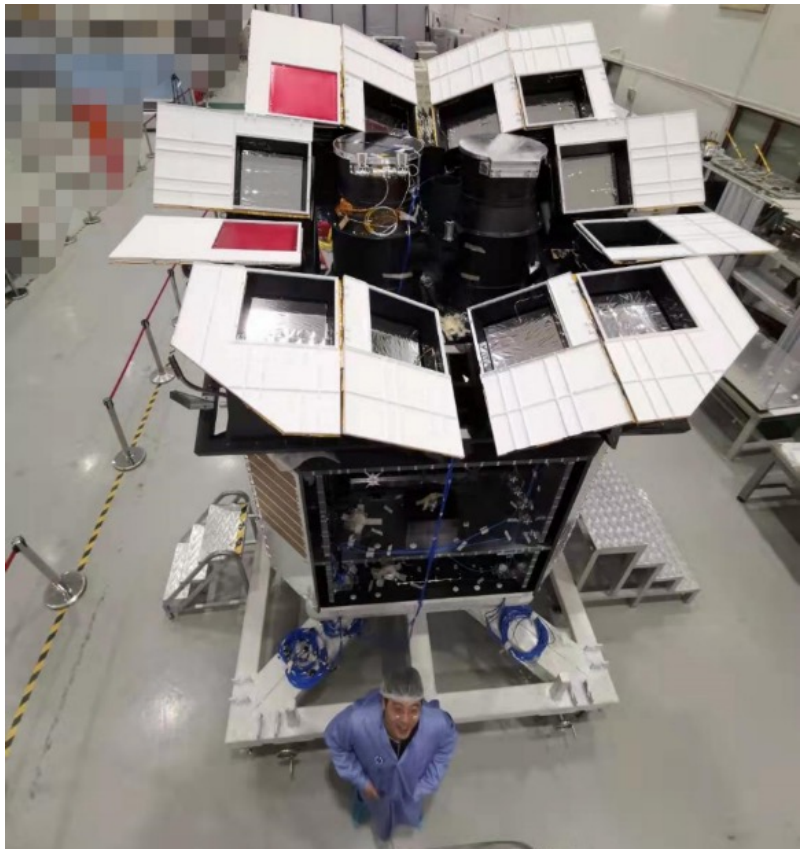




X-ray camera QM

Satellite status

- Satellite STM built and tested by MicroSat/CAS in 2019
- QM to be built by June 2021, afterwards Phase-D

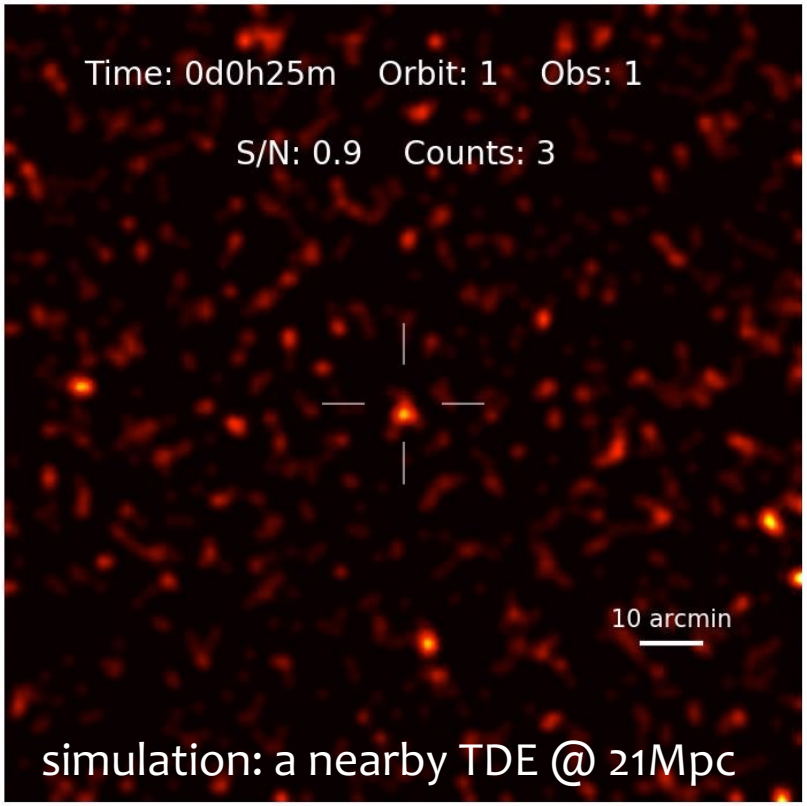


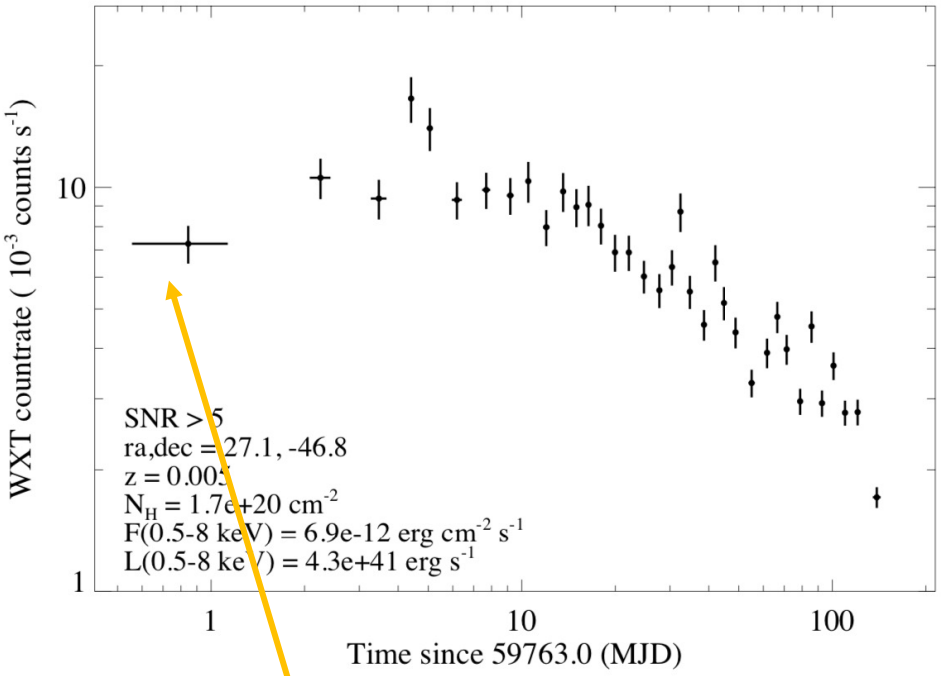
Estimated detection rates for some transients

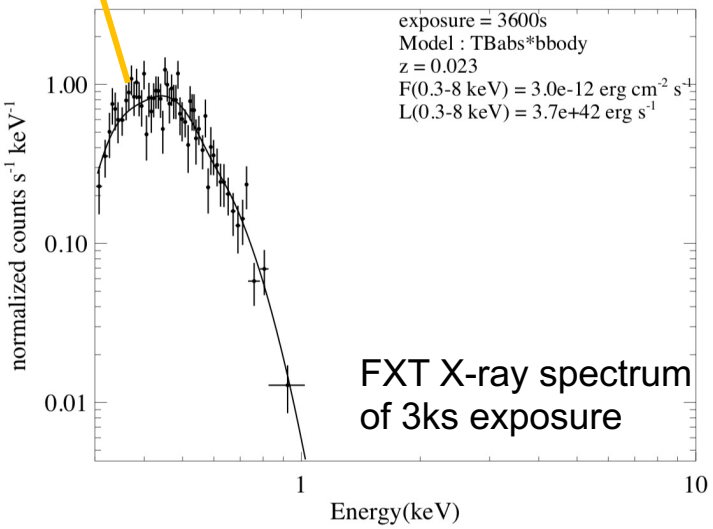
Type of transients	detections per year
Tidal disruption event (TDE)	tens - 100
TDE with jet	10 ?
Supernova shock breakout	10 (?)
Long GRB	~ 80
High-z GRB (z > 6)	several
Short GRB	~ 10
Low-luminosity GRB	~ 10
Magnetar	a few
Stellar flares	several 10^3
AGN monitored daily/weekly	tens/hundreds

challenging to identify!

Example: simulated detection of a nearby TDE







FXT X-ray spectrum of 3ks exposure

$M_{BH} \sim 10^4\ M_{Sun}$ IMBH

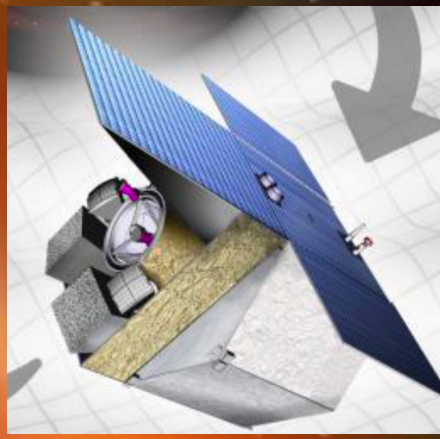
$L_{0.5-4keV} = 4.3\times10^{41}\ ergs^{-1}$

$f_{0.5-4keV} = 7\times10^{-12}\ ergs^{-1}cm^{-2}$

Summary

- The future of monitoring the transient X-ray sky is promising enabled by Lobster-eye MPO technology
- EP will be a powerful mission in this field in the years to come
- Synergy with other M-W & M-M facilities offers great science opportunities
- Follow-up by ground-based telescopes are needed
- EP will be a good pathfinder for THESEUS, esp. in soft X-ray MPO technology and science

Thank colleagues and friends in European community for long-standing support and interest in EP!
Good luck for Theseus!



http://ep.nao.cas.cn