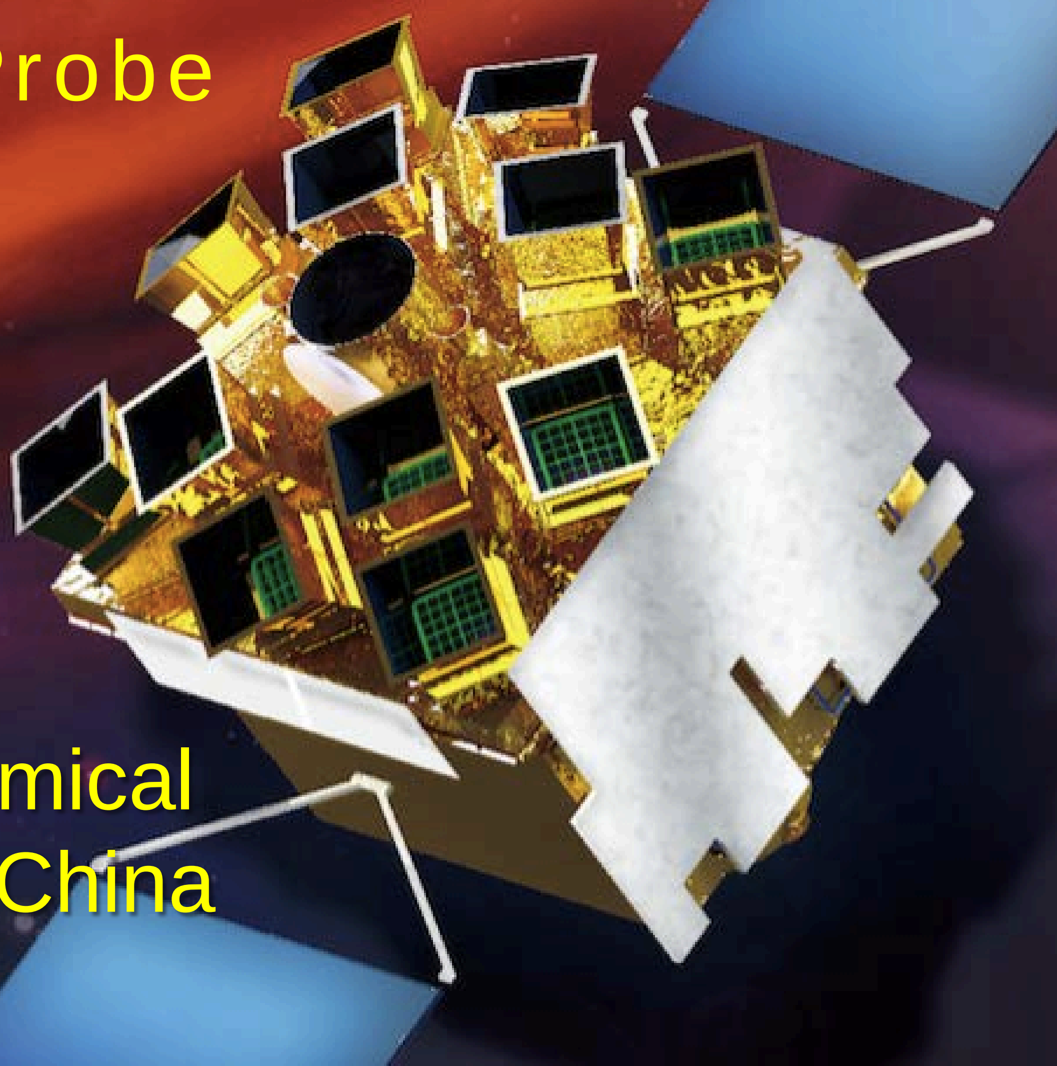
Calibration plans for WXT on Einstein Probe



Yuan Liu

National Astronomical Observatories of China

Current status

- A small mission for all-sky monitoring to discover and study X-ray transients
- Approved in Dec 2017, fully funded in 2nd phase of the space science program of CAS
- July 4th, 2018: formal announcement by CAS
- Currently in Phase B (design phase)
- Oct 2019: start Phase C (qualification model)
- Expected launch: Dec 2022

Team and international collaboration

http://ep.bao.ac.cn

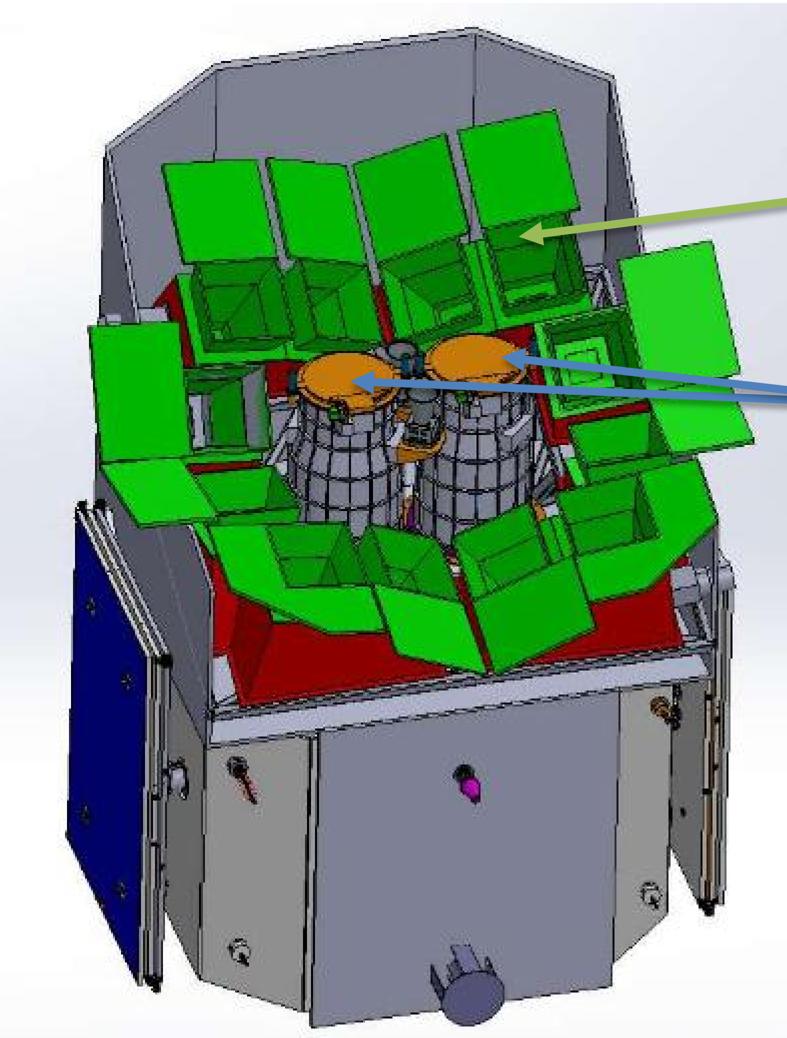
National Astron. Observatories of China (NAOC) CAS

Institute of High-energy Physics (IHEP) CAS

Shanghai Institute of Technical Physics (SITP) CAS

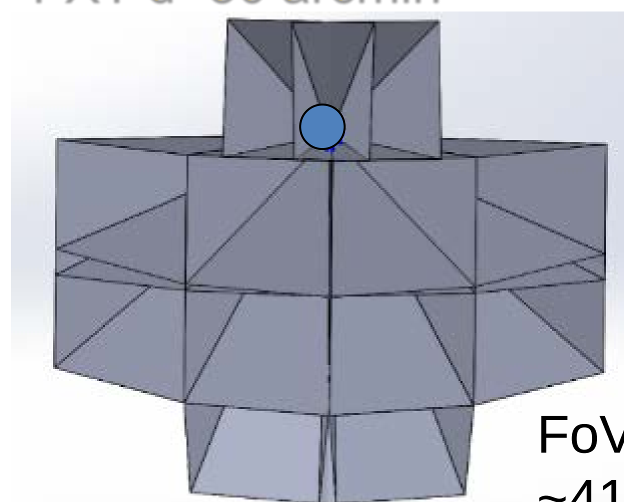
Shanghai Micro-Satellite (Microsat) CAS

EP Payloads



- Wide-field X-ray Telescope (WXT): lobster-eye MPO + CMOS (12 modules)
- Follow-up X-ray Telescope (FXT): Wolter-I + pnCCD (two modules)

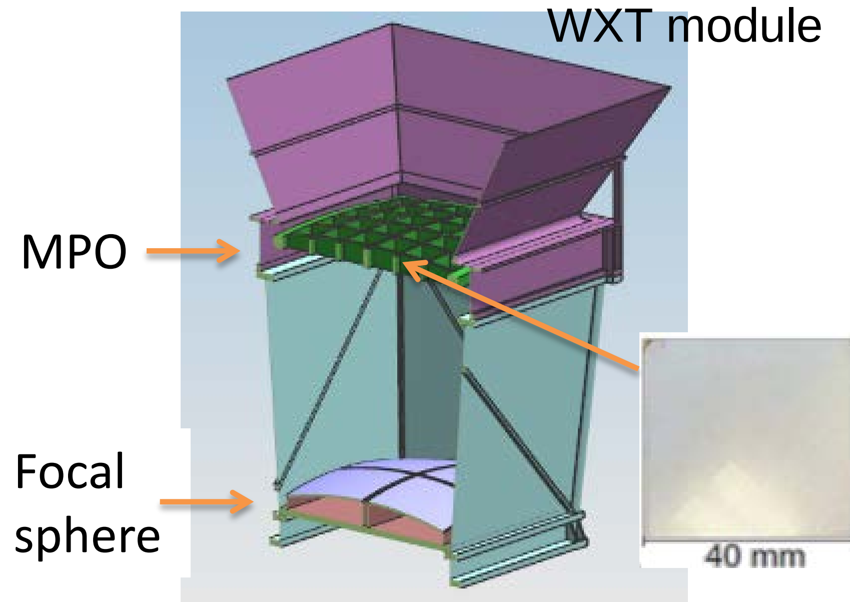
FXT d~30 arcmin

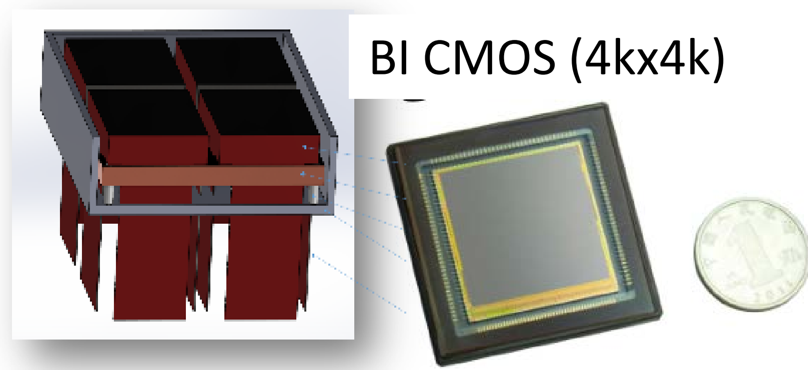


FoV of WXT
~4100 deg^2

Wide-field X-ray Telescope (WXT)

- X-ray optics: lobster-eye MPO (MPO plates China)
- Detector: large format, BI CMOS array (China)
- Eff. area: ~3 cm^2 @1keV
- FoV: ~4100 sqr. deg.
- FWHM: ~5 arcmin
- Bandpass: 0.5-4.0 keV
- Readout: 50 ms per frame
- Lead: SITP & NAOC (CAS)



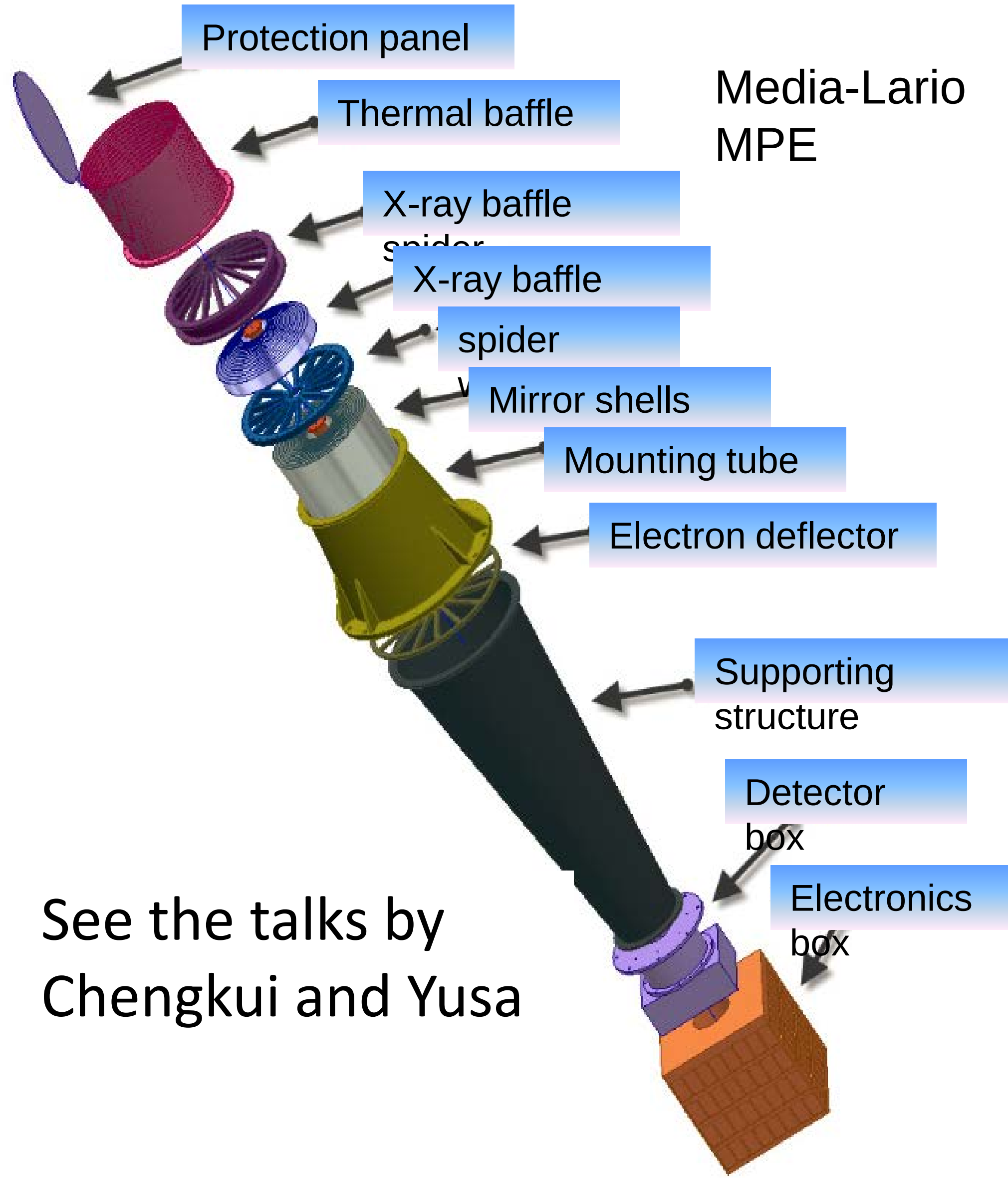


Challenge: the largest-format detector for focusing X-ray telescopes ever built

Follow-up X-ray Telescope (FXT)

- X-ray optics: Wolter-I
- Detector: PN-CCD (MPE)
- Focal length: 1.6m
- Eff. area: >120cm^2 @1keV
- FWHM: < 2 arcmin

  30” goal
- FoV: ~30 arcmin
- Bandpass: 0.3-10 keV
- Lead: IHEP (CAS)

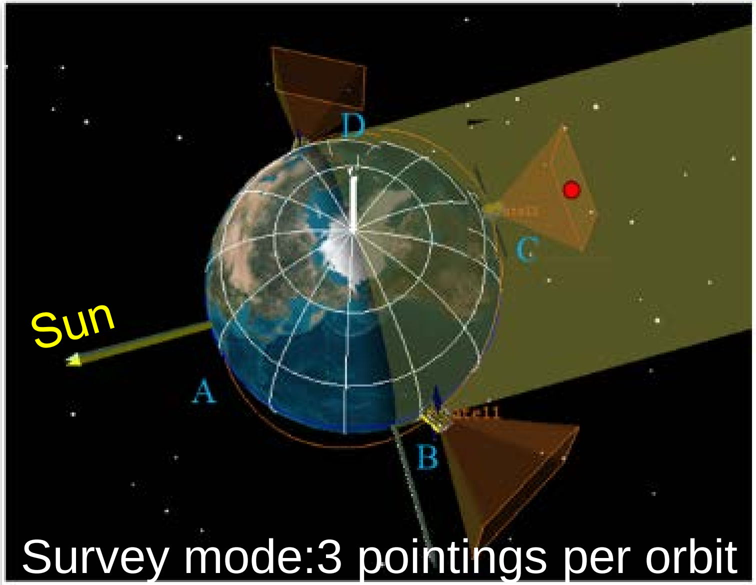


Media-Lario
MPE

See the talks by Chengkui and Yusa

Mission profile

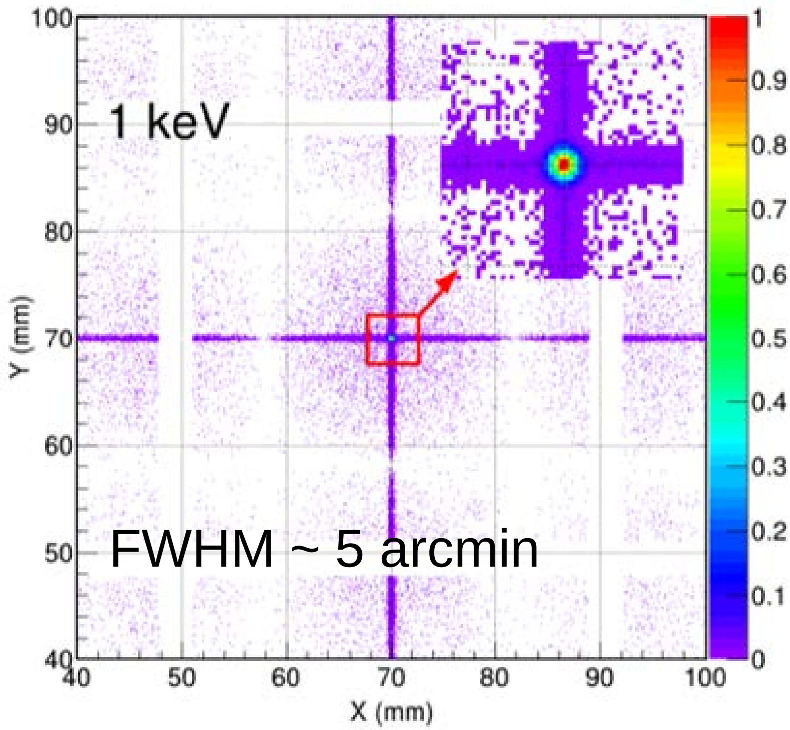
- Orbit: ~600 km,   i ~30 deg
- Observation modes
  - **Survey**: 3 pointings per orbit to the night-sky, each ~20 min exposure
  - cover whole night sky in 3 orbits
  - **On-board trigger: FXT follow-up**
  - **ToO**
- On-board data reduction & transient search
- Alert data downlink/uplink
  - Baseline: 'Beidou' system
  - backup: VHF network (French)
- Nominal lifetime: 3 +2 years

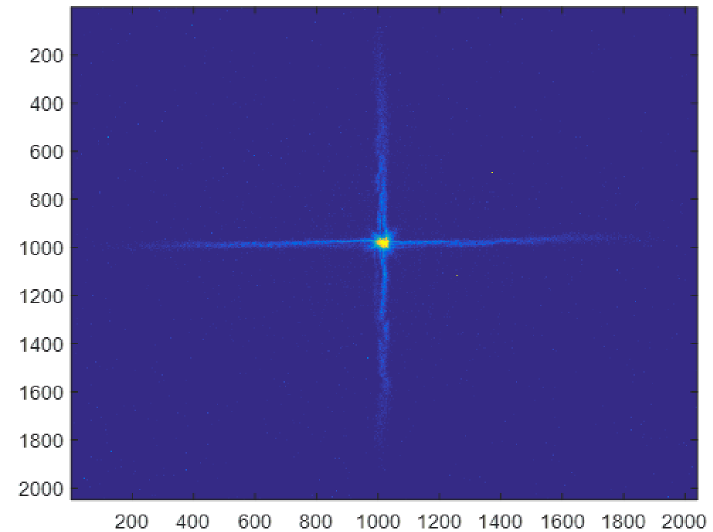


Survey mode:3 pointings per orbit

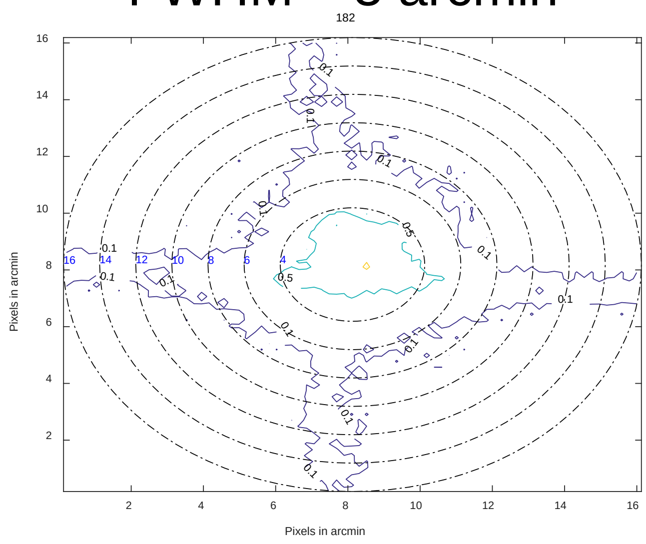

Beidou Navigation system

Performance of WXT: angular resolution





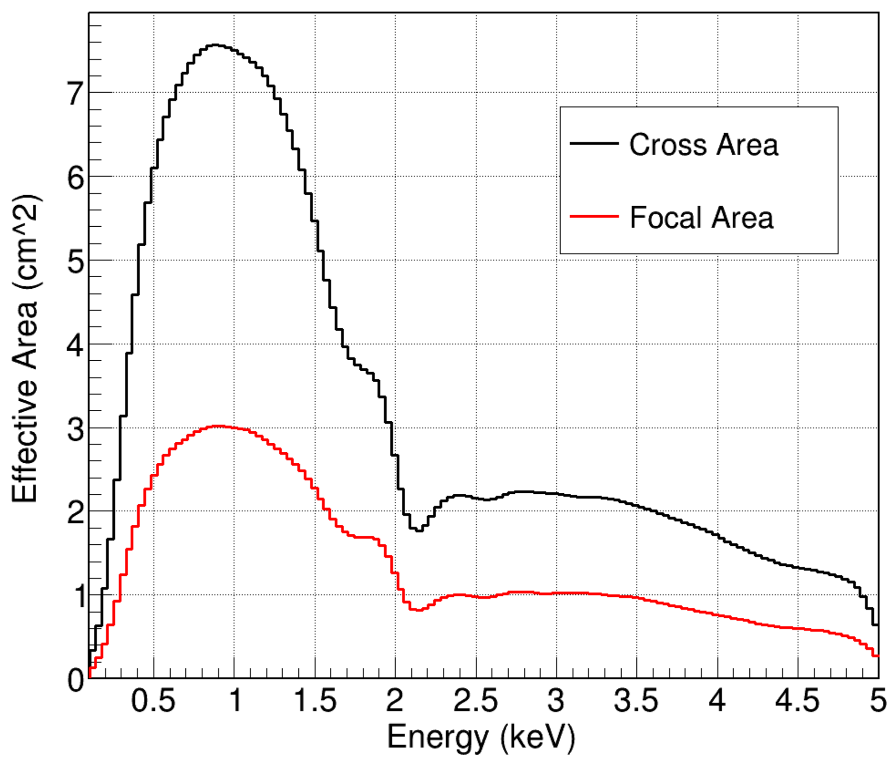
Measured PSF (NAOC)
FWHM ~ 5 arcmin

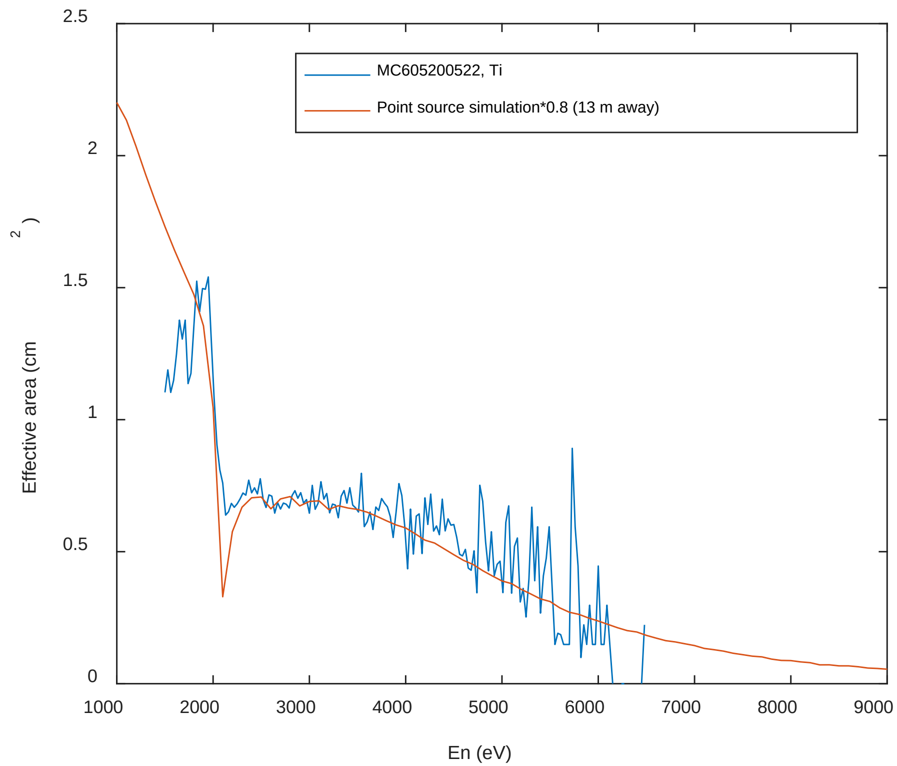


Zhao et al. 2014
SPIE (9144)

Performance of WXT MPO: effective area

Effective area: simulated vs. measured



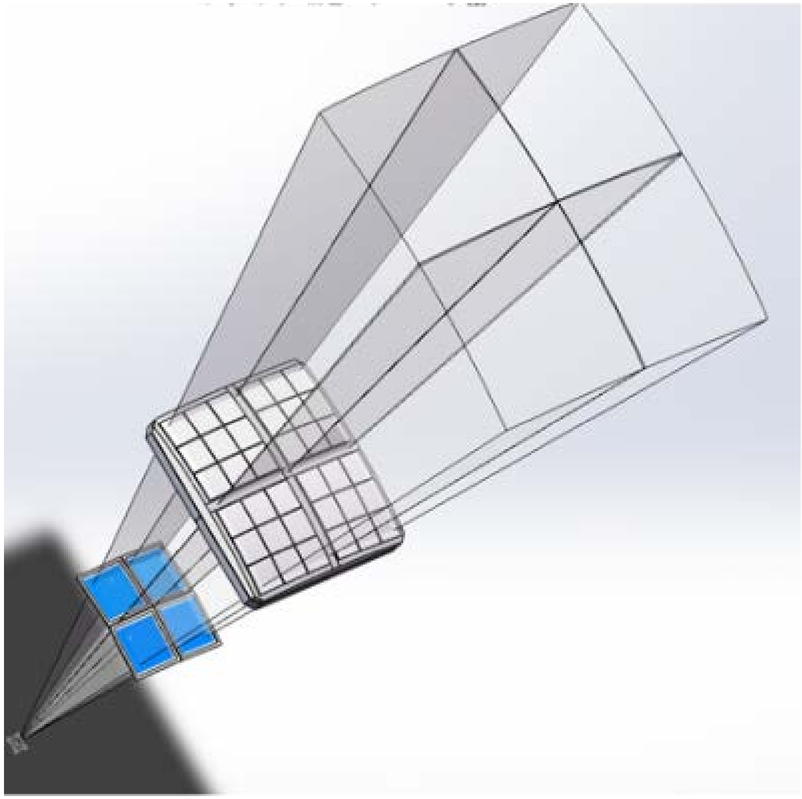


Zhao et al. 2014 SPIE (9144)

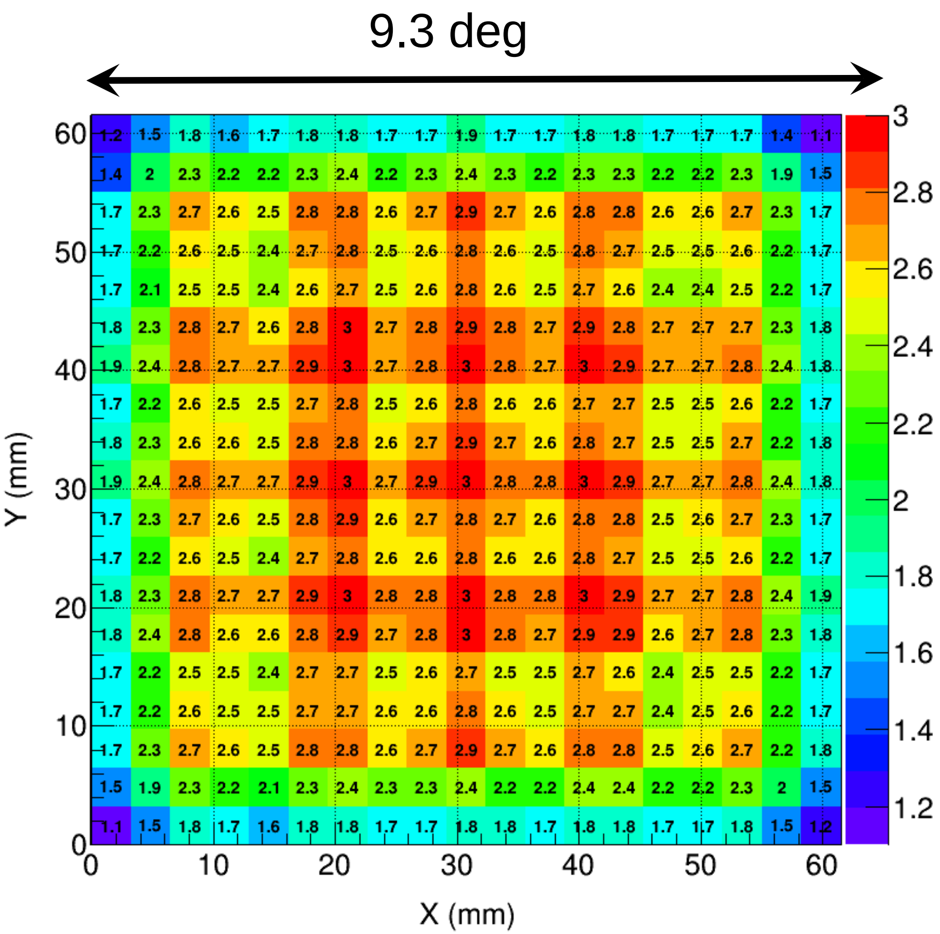
NNVT MPO plates is getting close to (80%) the theoretical value

Effective area

- Complex distribution: fewer MPO chips at the edge, supporting structure



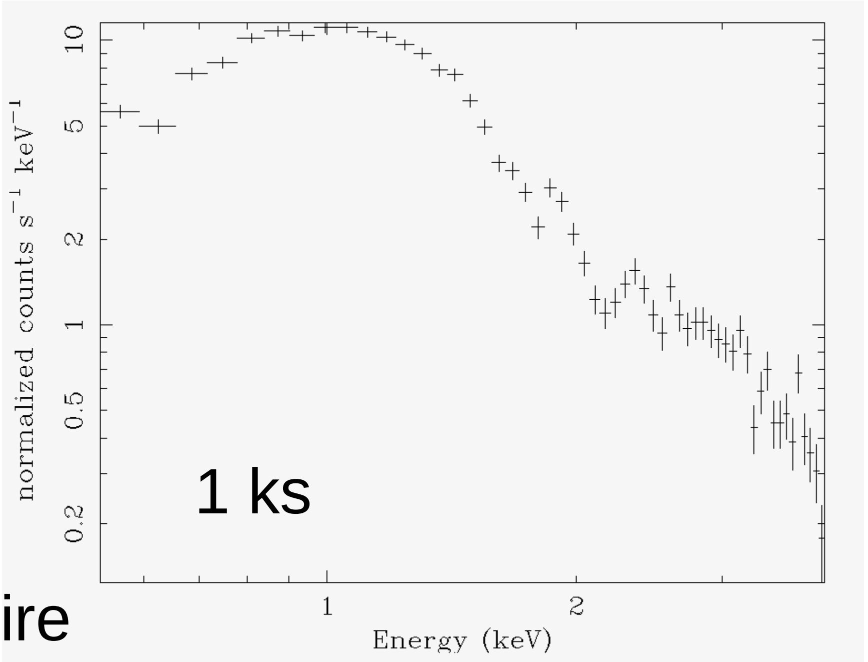
4 independent sub-modules



Eff. Area @ 1 keV

Simulated spectrum of Crab

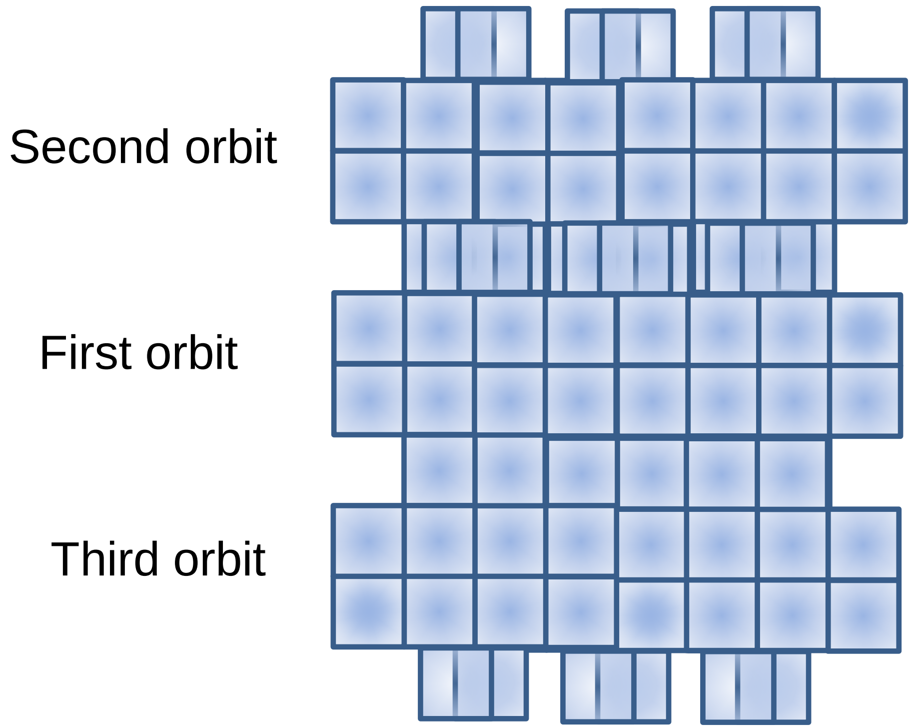
- 1 Crab (WXT) = 12 ct/s
- 2% stat error of spectral index
- 3.5% stat error of norm
- 9.3 deg x 9.3 deg
- 1 deg grid for one sub-module
- 81x48 pointing obs
- Need ~3 months to map the entire FoV of WXT
- No dedicated calibration campaign
- Complete such task during the sky survey



Survey strategy

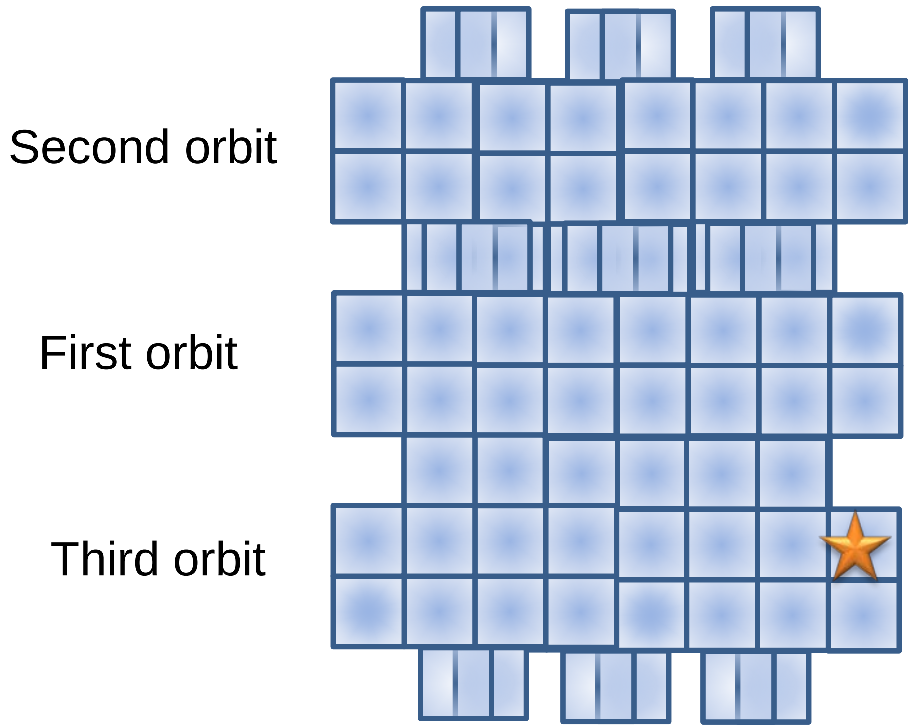
3 pointings per orbit

cover whole night sky in 3 orbits



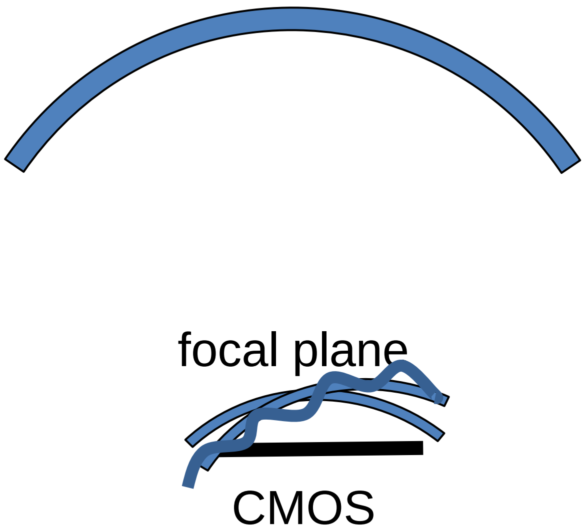
Survey strategy

The coverage shifts as the Earth's revolution (1 deg per day)



Tilt some pointing obs to
map the entire FoV of WXT

Astrometric calibration



- Ideal focal plane (a sphere)
- CMOS (a plane)
- Ideal projection is easy
- Tilted, curved, distorted
- Need non-linear correction
- Common for optical telescope
- Fourth-order polynomial for ZTF (47 deg^2)
- Much fewer (bright) sources in X-ray

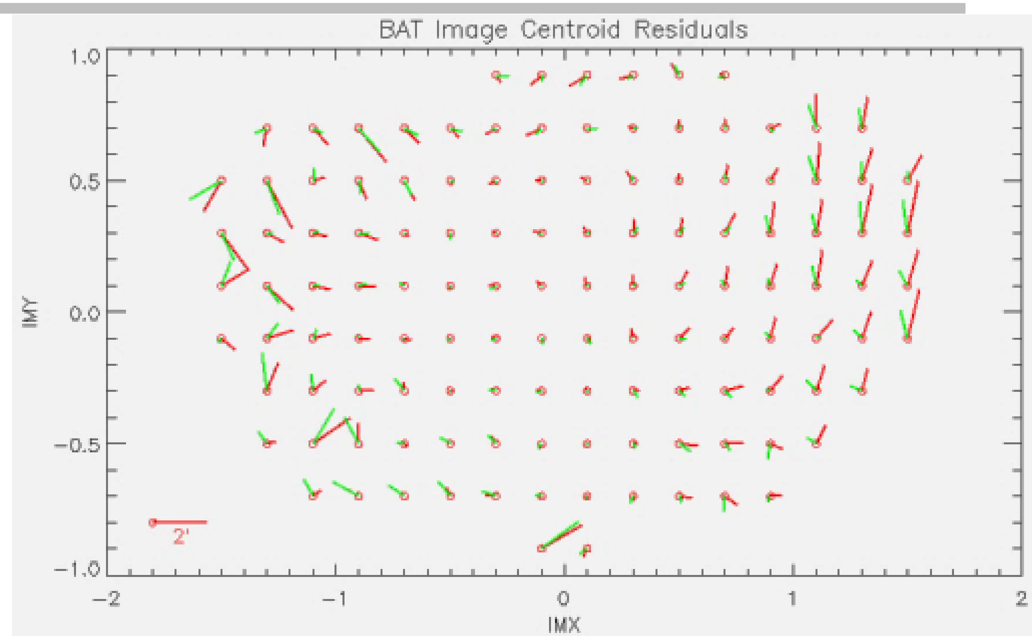
Detector => tangential coordinates

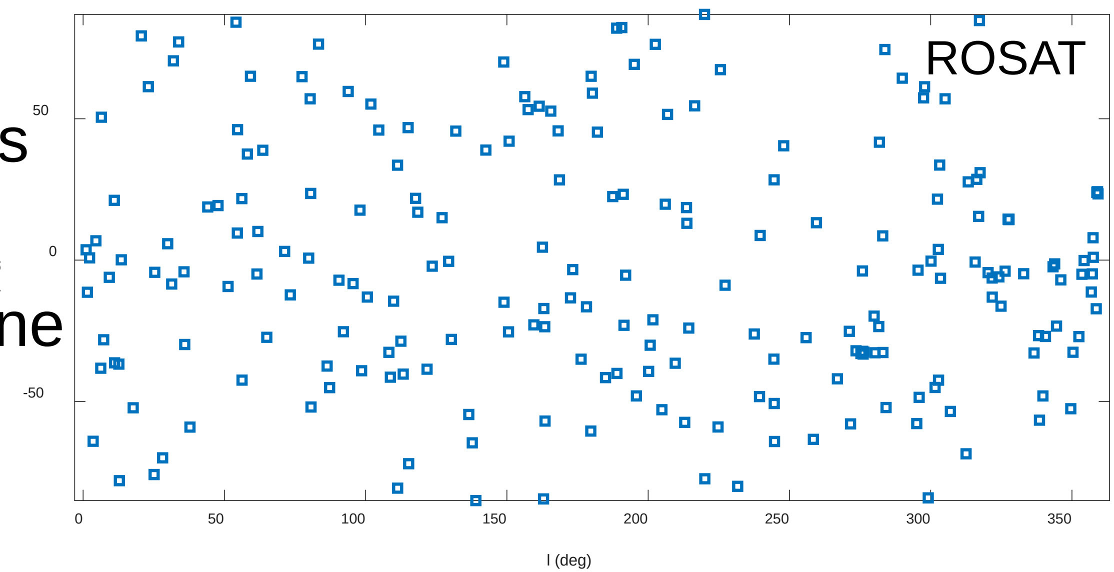
$$\xi = a_1 x + a_2 y + a_3 + a_4 x^2 + a_5 xy + a_6 y^2 + a_7 x^3 + a_8 x^2 y + a_9 xy^2 + a_{10} y^3 + a_{11} m + a_{12} CI + \ldots$$

$$\eta = b_1 y + b_2 x + b_3 + b_4 y^2 + b_5 yx + b_6 x^2 + b_7 y^3 + b_8 y^2 x + b_9 yx^2 + b_{10} x^3 + b_{11} m + b_{12} CI + \ldots$$

Astrometric calibration

- The requirement of WXT positional error is 1 arcmin (systematic)
- Swift/BAT adopts a distortion map (spline function)
- Monitor bright sources (>1 mCrab) during all sky survey
- No more than 10 sources in one pointing
- Low order poly or combine exposures





Summary

- The task of WXT is to ‘discover’ new transients
- The performance of WXT model is approaching the requirement (PSF, eff. area, energy resolution)
- The large FoV of WXT requires plenty of time to calibrate it
- “Calibrating in survey” is the natural and feasible way

http://ep.bao.ac.cn