Einstein Probe (EP) mission

(Wide-field X-ray Telescope, WXT)

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

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Einstein Probe (爱因斯坦探针卫星) mission team

Einstein Probe mission overview

- Satellite profile
  - Weight: ~1400 kg, Power ~1100 W
  - Orbit: 600 km, inclination ~ 29 deg. (Xichang, 西昌, 四川)
- Science instruments
  - WXT (Wide-field X-ray Telescope) 12 units. 0.5-4 keV (soft X-ray)
    - Lobster-eye X-ray mirrors + BI CMOS - products of Chinese Companies
    - One-unit FOV = 9x9 deg^2 x4. Total 3600 deg^2 = 1.1 sr
  - FXT (Follow-up X-ray Telescope) 2 units. 0.3-10 keV
    - Walter-I mirror + PN CCD
    - FOV: phi=30 arcmin.

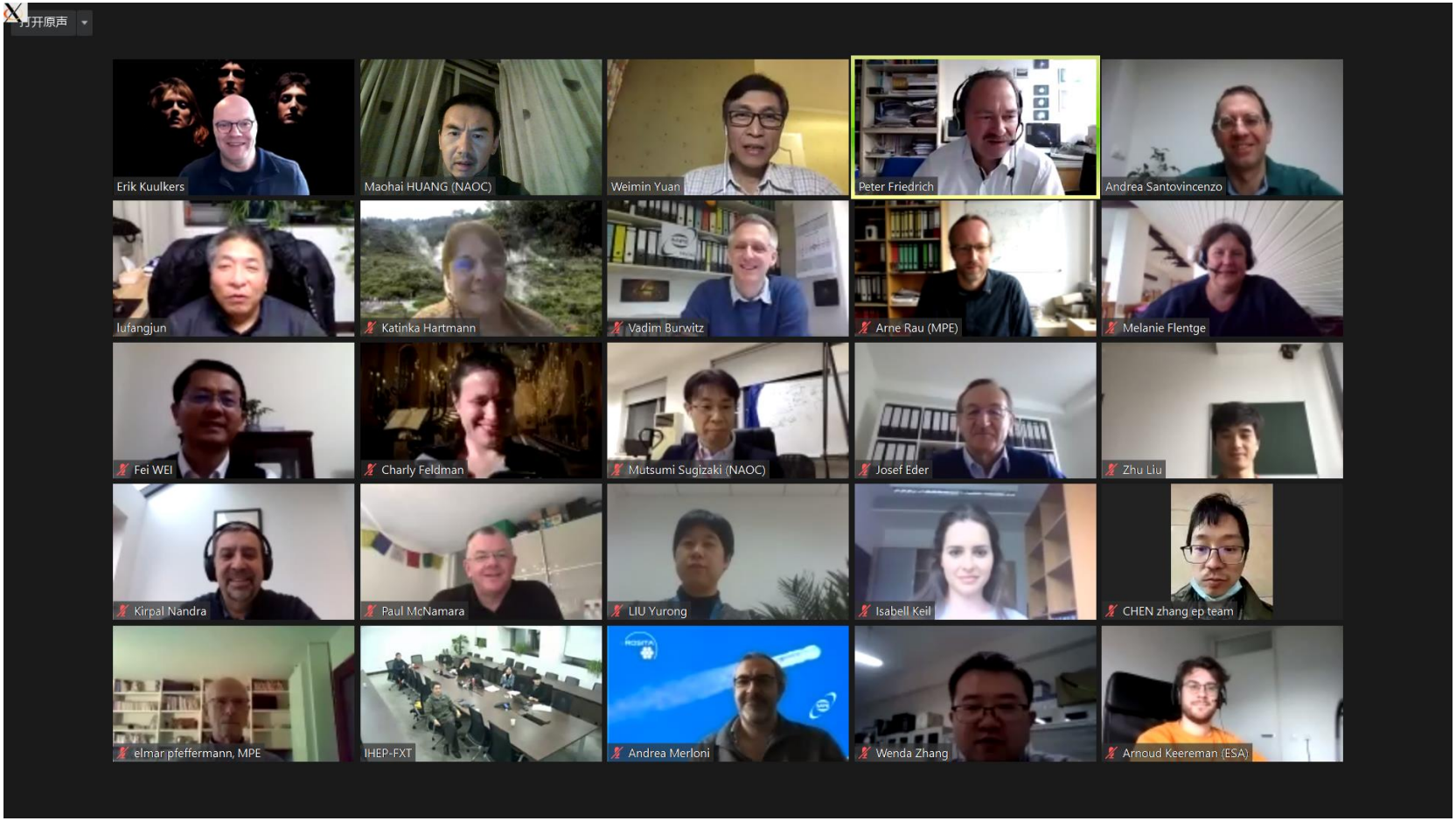
- Schedule
  - 2019/12 Qualification modeling (Phase C)
  - 2021/03 Flight production (Phase D)
  - 2022/12 launch

Collaboration Team

- China
  - National Astronomical Observatories, CAS (NAOC)
  - Institute of High Energy Physics, CAS (IHEP)
  - Shanghai Institute of Technical Physics, CAS (SITP)
  - National Space Science Center, CAS (NSSC)
  - Shanghai Micro-Satellite (Microsat)
  - Chinese Academy of Launch Vehicle Technology

- Outside of China
  - European Space Agency (ESA)
  - MPE, Germany
  - CNES, France

Zoom collaboration meeting in 2020 Nov.



NAOC team members

Operation plan

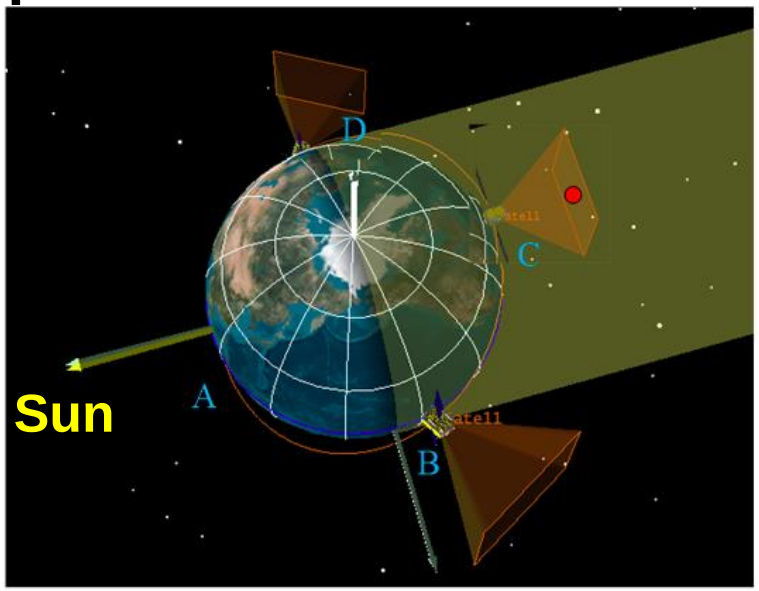
- Operation modes
  - Survey: 3 pointing per orbit, each ~20 min exposure to cover whole night sky in 3 orbits (~4.5 hour).
  - On-board WXT data reduction and triggering FXT follow-up of new transients.

    Maneuver time: 60 deg / 3 min.
  - ToO observations.

- Alert downlink
  - Baseline: Beidou system (30 sat.)
  - Backup: VHF network (French)

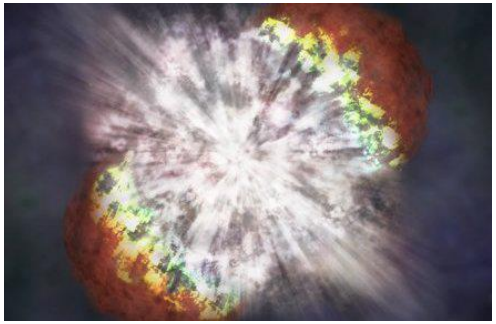
- Quick ToO command
  - Baidou system: latency < 10 min

- Mission life
  - Nominal 3 +2 years

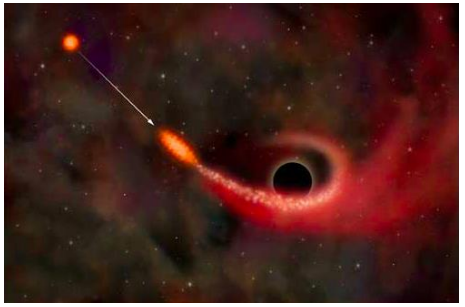


Main scientific objectives

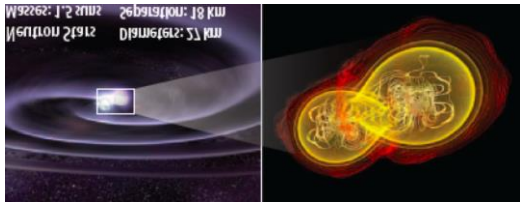
- Monitoring soft X-ray transients and variable sources with unprecedented sensitivity and high cadence



- Discovering normally quiescent black holes at all astrophysical mass scales by capturing the transient flares, particularly TDE from SMBHs

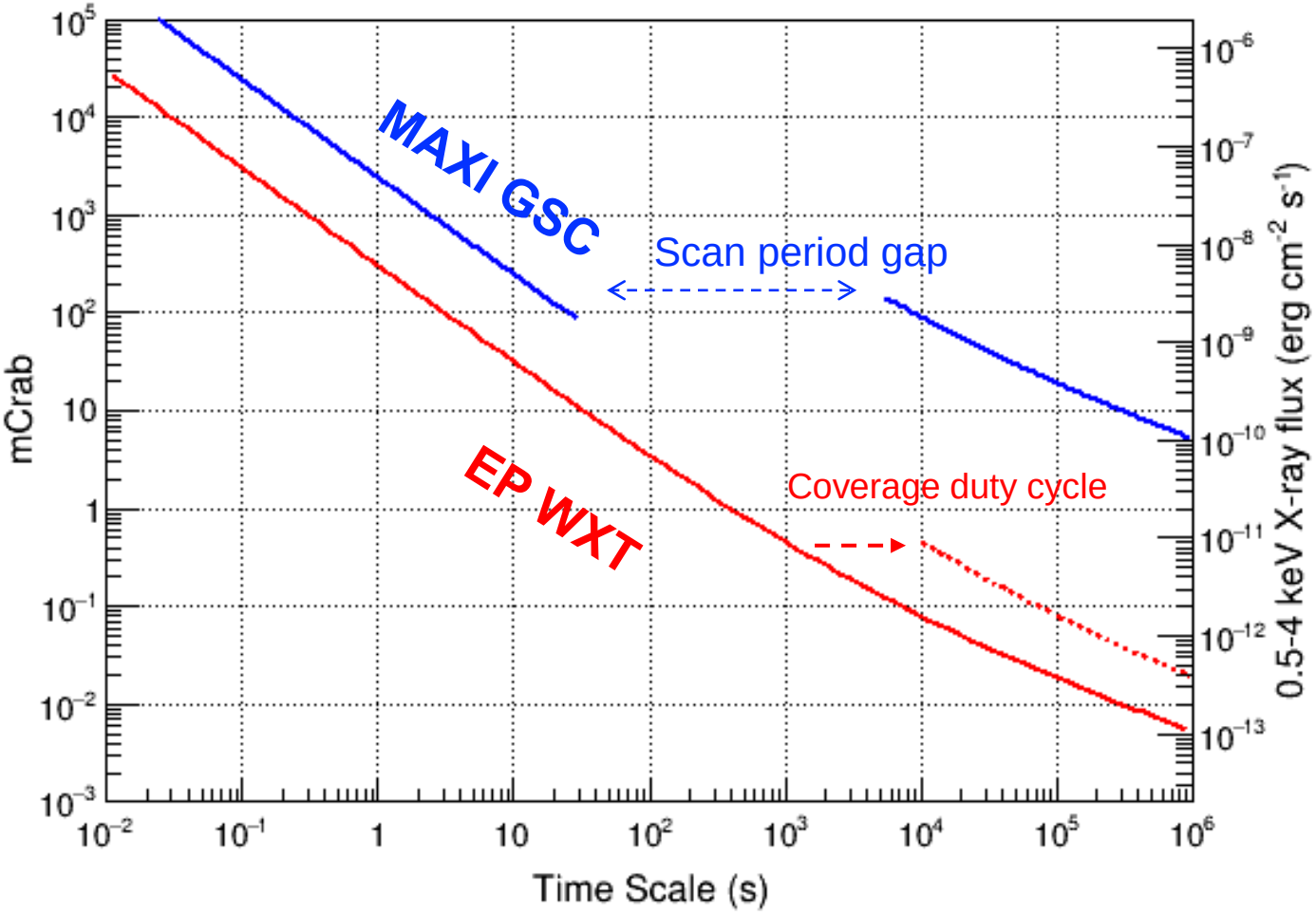


- Soft X-ray counterpart search for gravitational-wave events, fast radio bursts (FRBs), ….



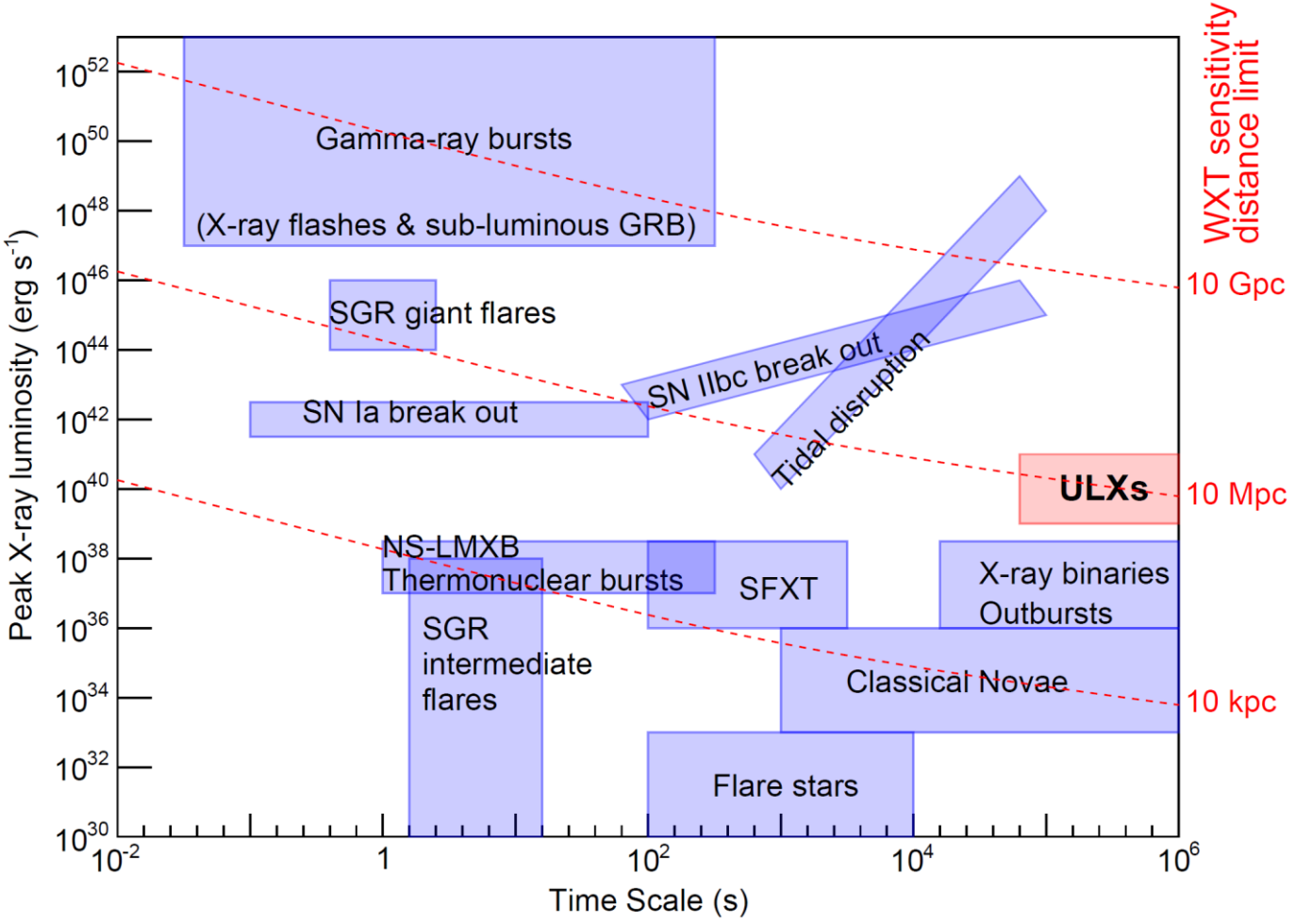
- Finding new types of soft X-ray events

EP WXT Sensitivity



EP sensitivity (Yuan 2018)
MAXI sensitivity (Negoro 2016)

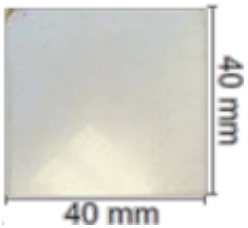
Target space in soft X-ray time domain astronomy

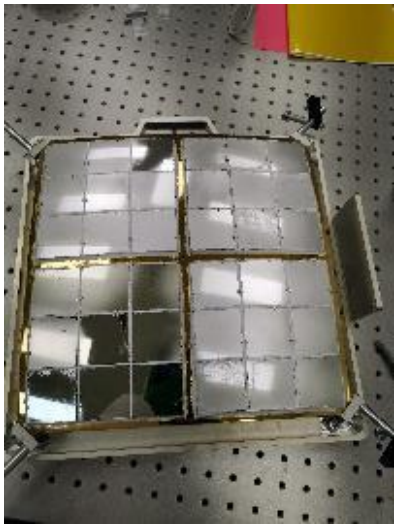


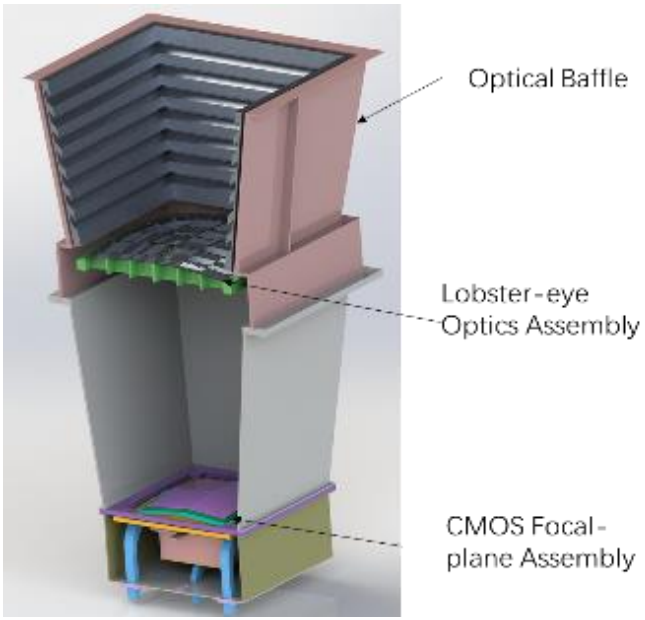
EP sensitivity (Yuan 2018)

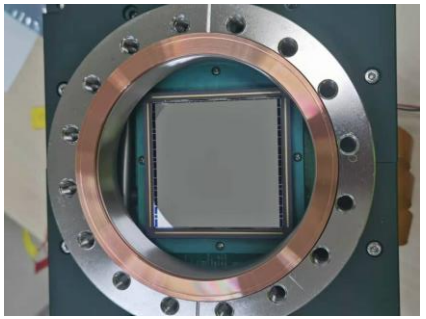
Wide-field X-ray Telescope (WXT)

- Lobster-eye X-ray mirrors (NNVT, China) + BI CMOS (Gpixel, China)
- Total FOV = 1.1 sr with 12 WXT units
- Spatial resolution ~ 5’ (FWHM)
- Position accuracy < 1’
- Effective area ~ 3 cm^2 at 1keV
- Energy resolution: 170 eV at 1 keV
- Readout rate: 50 ms per frame



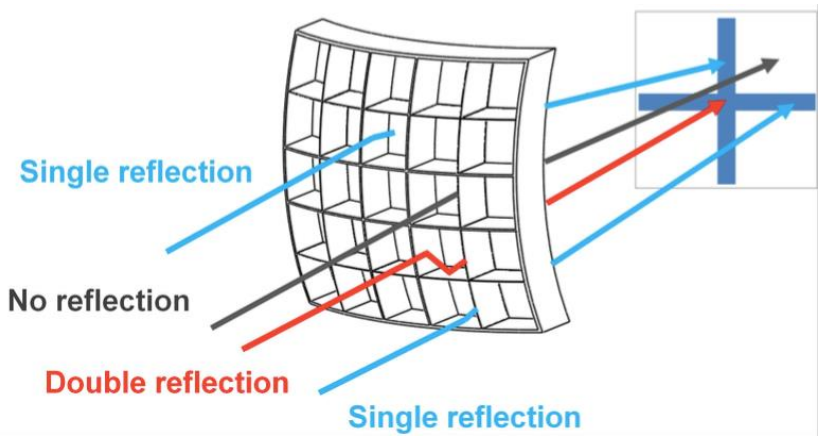






Lobster-eye optics

Schematic



Simulation

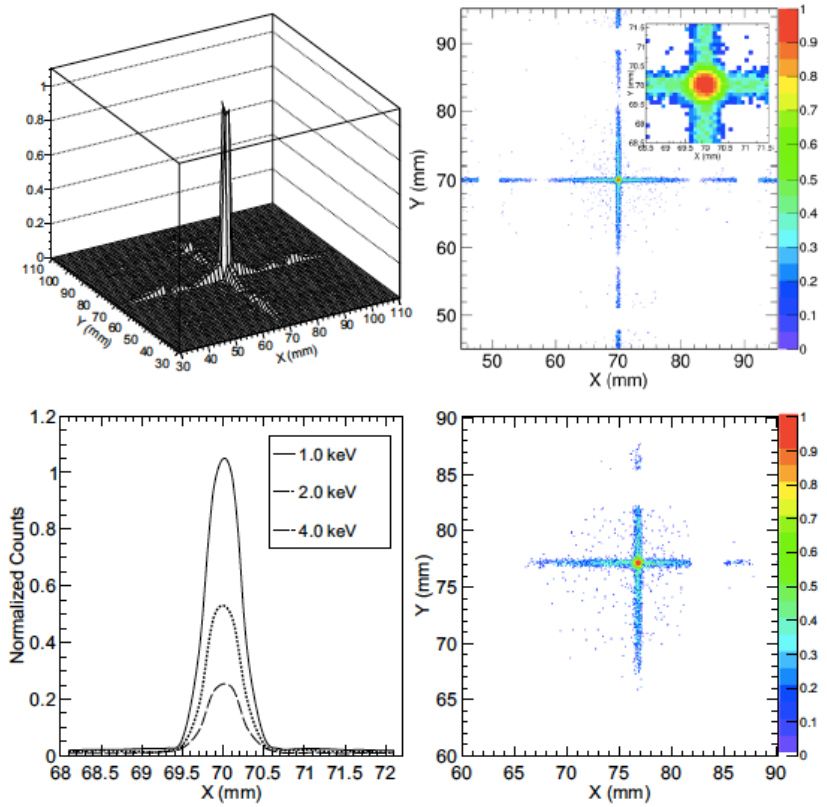
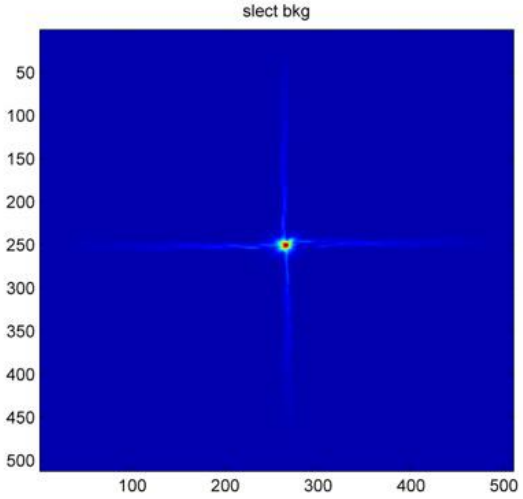


Fig. 3 The normalized PSF of the telescope described in Section 2 considering the surface roughness of about 0.55 nm and pore pointing deviation which follows a Gaussian distribution with σ=0.85 arcmin. Each PSF image is obtained by using 5×10^6 incident photons. (*top left*) The surface plot of PSF at 1.0 keV. (*top right*) The contour plot of the PSF when the 1.0 keV parallel X-ray beam is on axis. (*bottom right*) The PSF at 4.0 keV when the source moves to a position of 1.5° zenith angle and 45° azimuth angle. (*bottom left*) One dimensional PSF at different energy considering one central group of data along the X-axis of the detector. The color codes in the right two panels are in logarithmic scale

(Zhao et al. 2014)

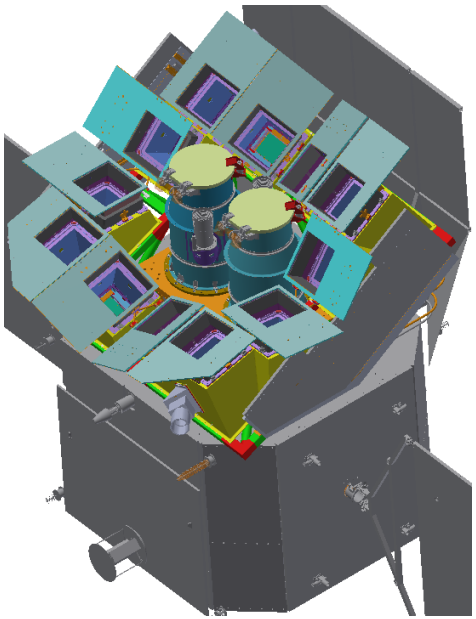
Measured PSF (NAOC)

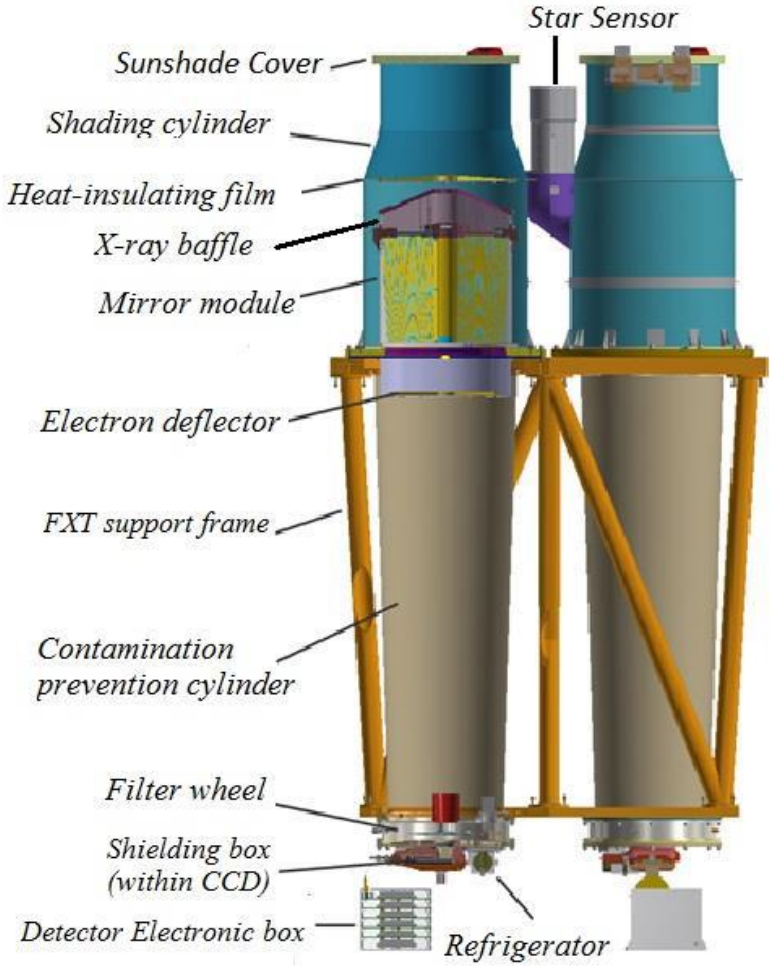


(Yuan et al. 2017)

Follow-up X-ray Telescope (FXT)

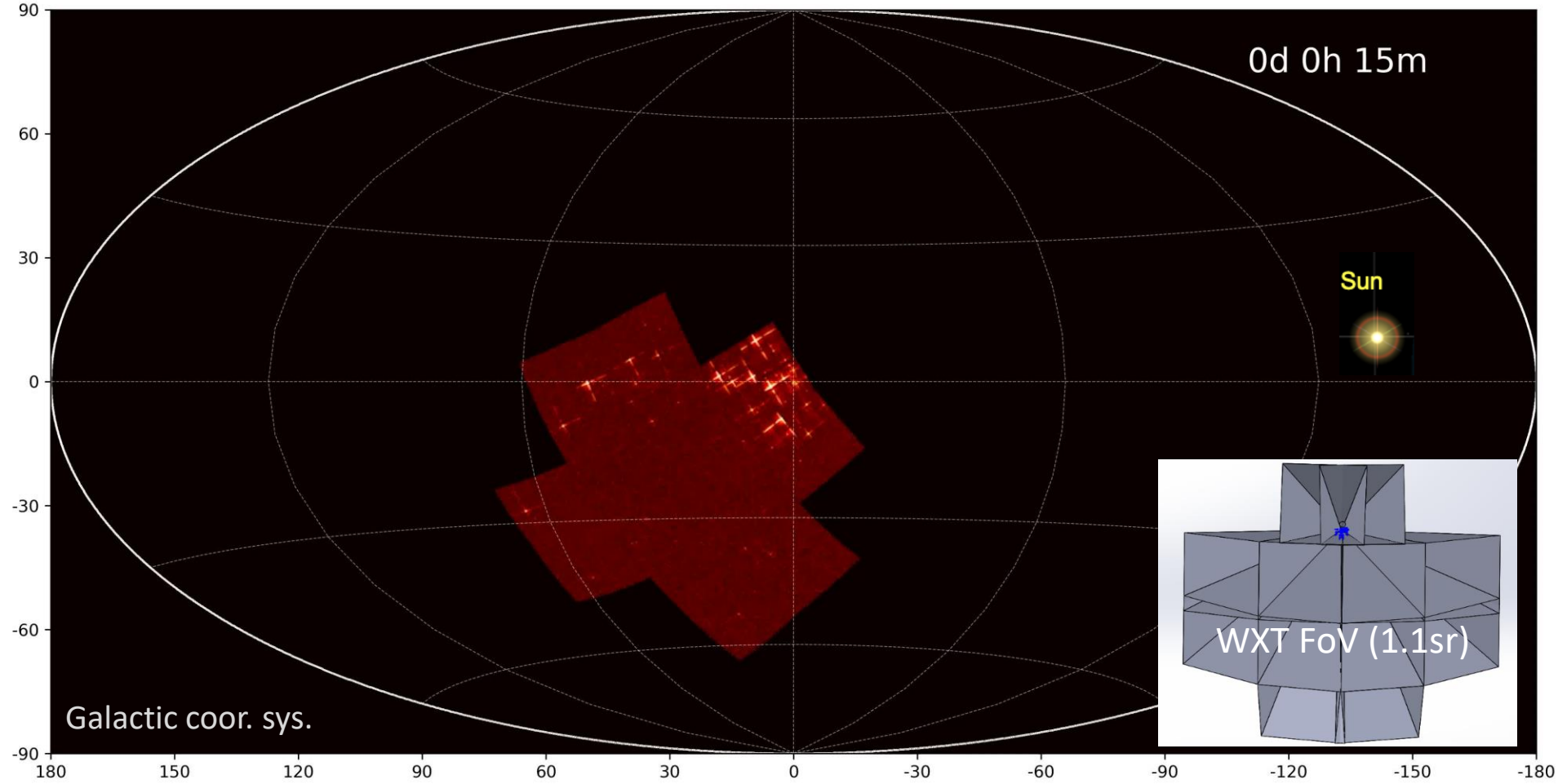
- 2 Walter-I mirror (1 MadiaLario + 1 eROSITA spare or Chinese product) + PN CCD (MPE) = nearly eROSITA module on SRG
- FOV phi 38’
- Spatial resolution 0.5’ (HPD)
- Position accuracy ~ 5”.
- Effective are 300 cm^2 @ 1keV
- Energy resolution: 170 eV @ 1 keV
- Readout rate: 1 s per frame





WXT feasibility prospects from data simulation and analysis

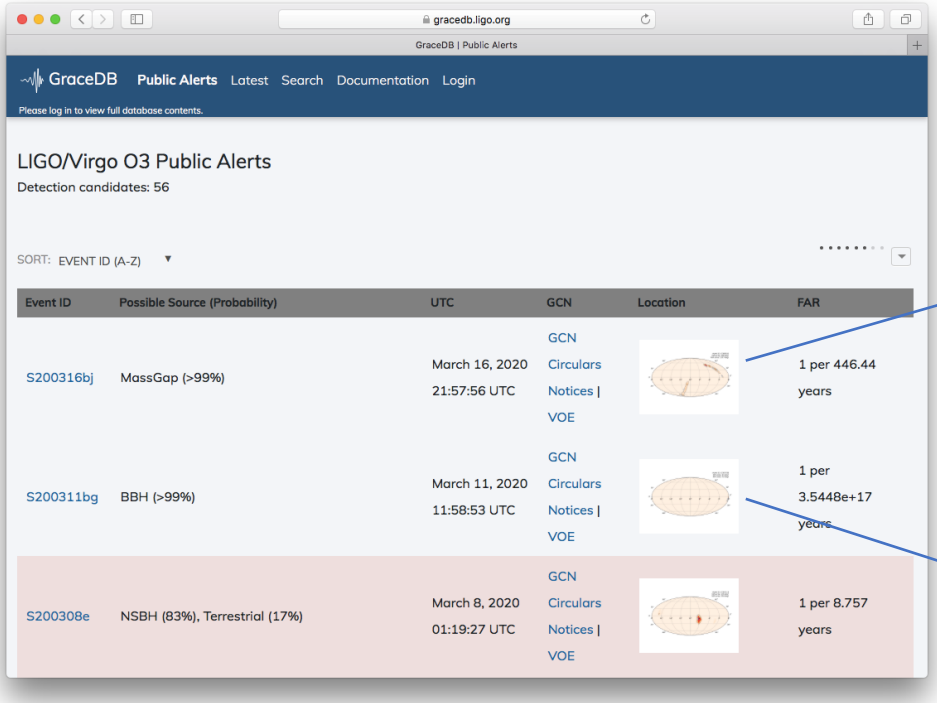
WXT survey monitoring footprints (1 day simulations)



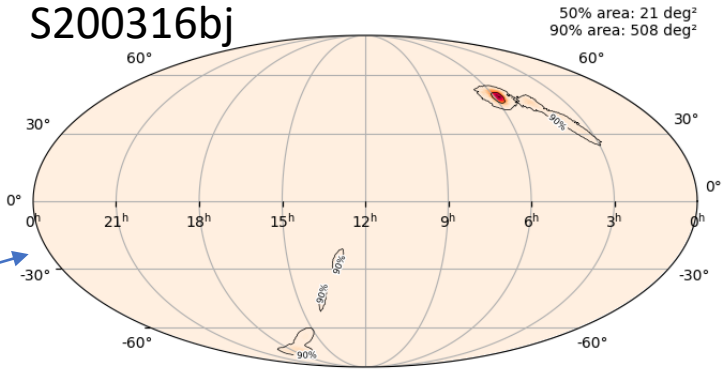
- In 3 orbits (~ 5hr) WXT covers most of the night sky (can be disrupted)
- Cover the whole sky in half year
- Synergy with other M-W & M-M facilities (LSST/SKA/Swift/SVOM/LIGO/...)

GW-counterpart search

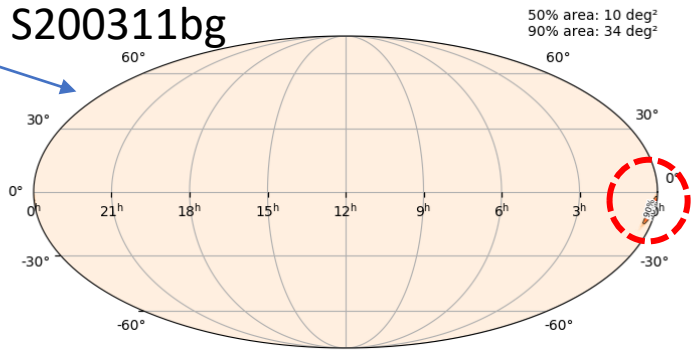
LIGO/Virgo O3 run (2019/3 -2020/4)
GW source alerts
https://gracedb.ligo.org/superevents/public/O3/



Confidence contours of
GW source location



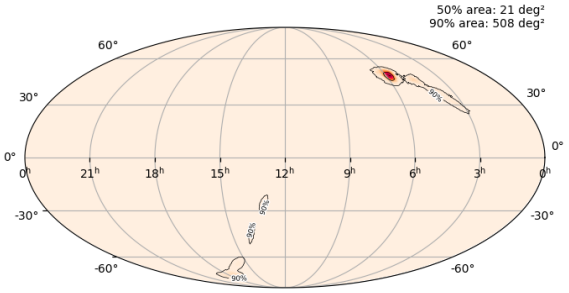
Typical error area



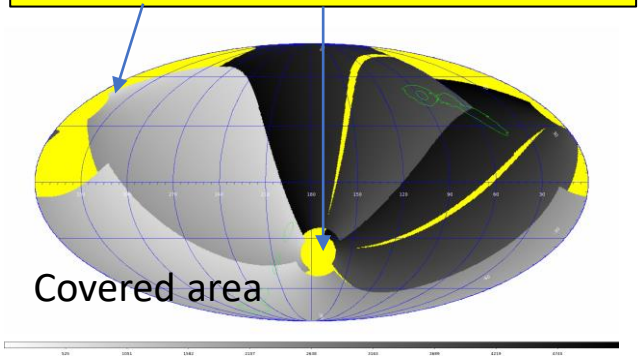
Very good case

Example in GW counterpart search with MAXI

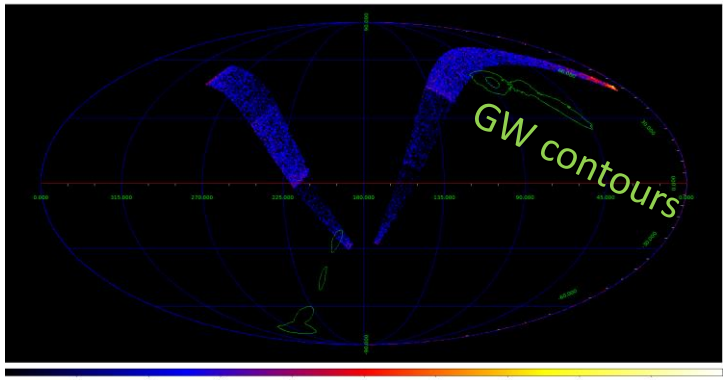
S200316bj
March 16, 2020
21:57:56 UTC (= T)



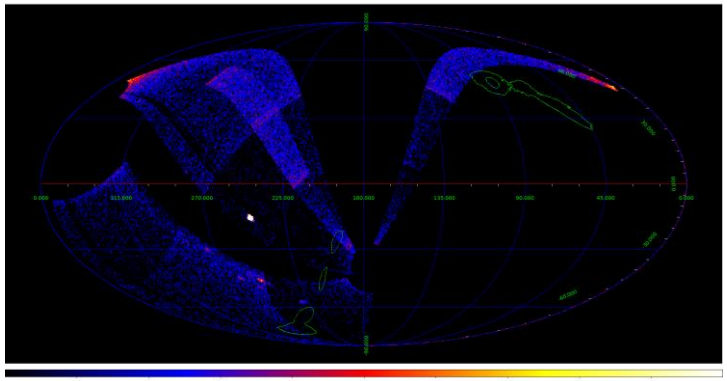
Uncovered area for high radiation zone, sun angle, and scan pole.



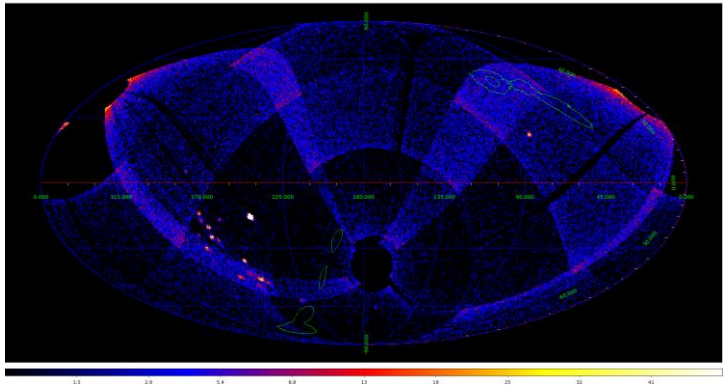
MAXI covers 85% sky by ~90 minutes.



MAXI event image on GW contours



T-5 min to T+5 min

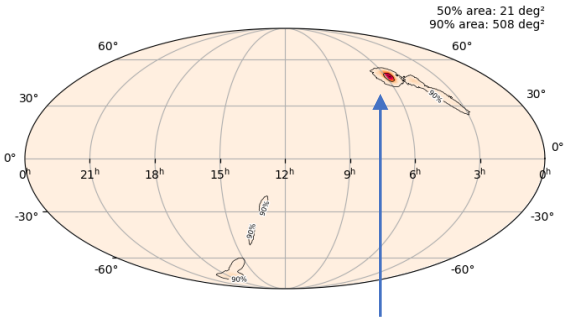


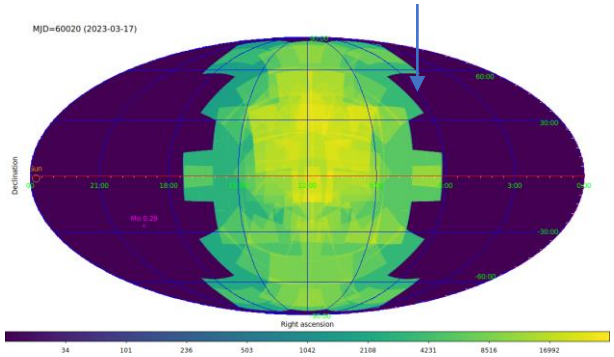
T-5 min to T+30 min

T-5 min to T=90 min

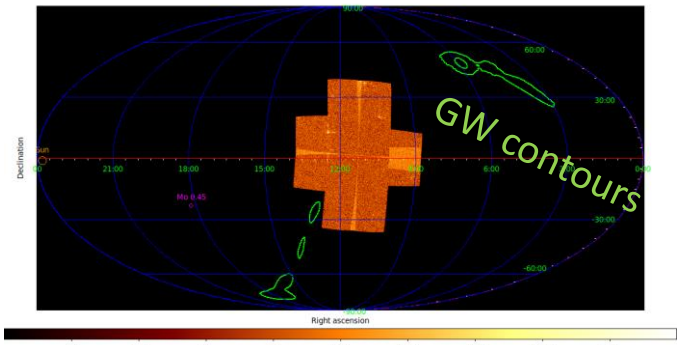
Tests with EP observation simulator (Preliminary)

Assume the event time
March 16, ~~2020~~ -> 2023
21:57:56 UTC (= T)



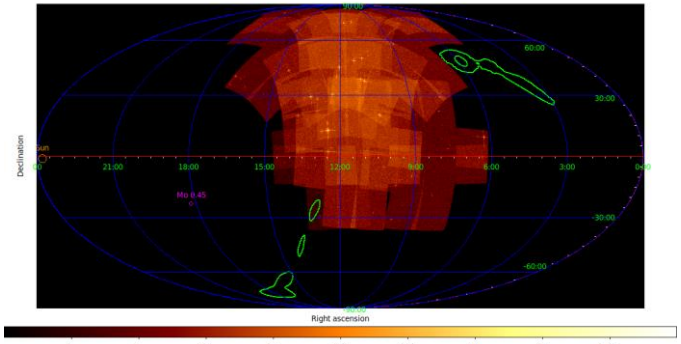


2023-03-16 WXT exposure map

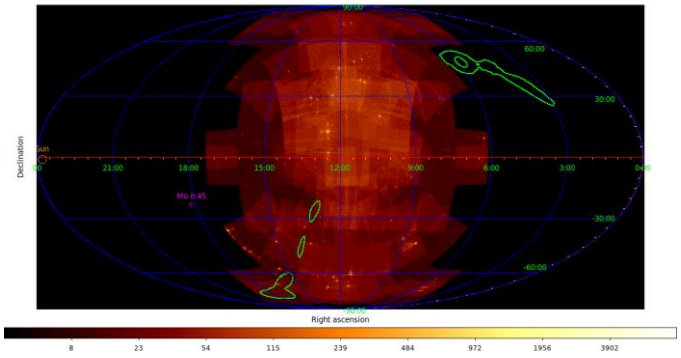


WXT event image on GW contours

T to T+45 min



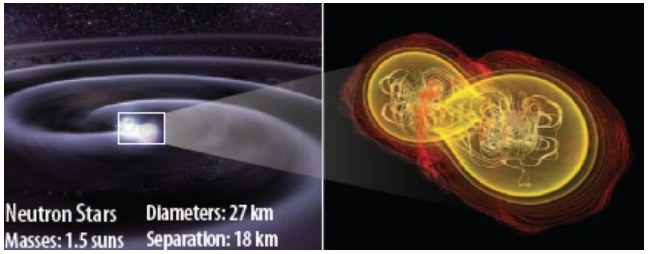
T to T+ 4 hr



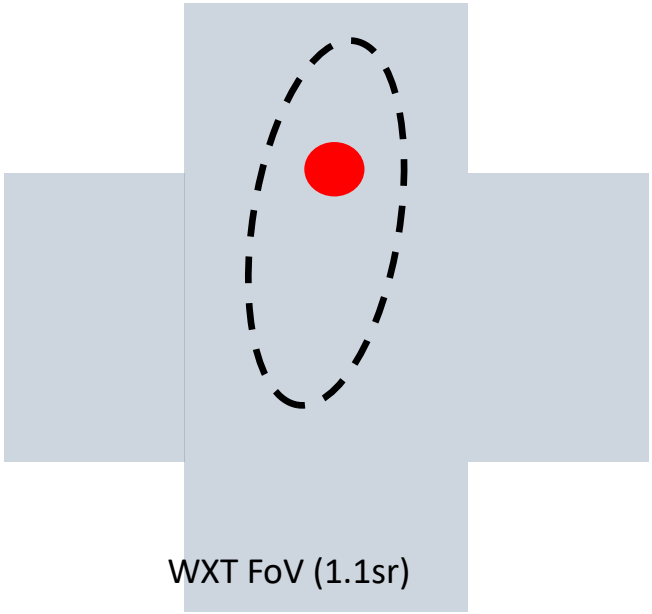
T to T+ 8 hr

Search for X-rays from gravitational wave events

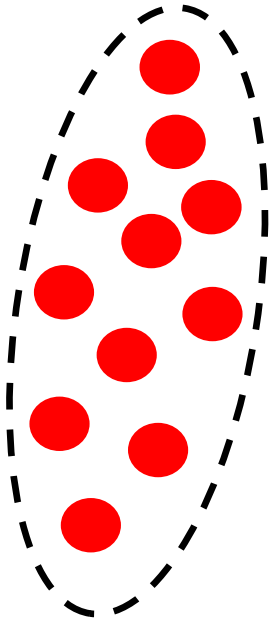
Quick ToO observation commands uplink within 10minuts after GW alert



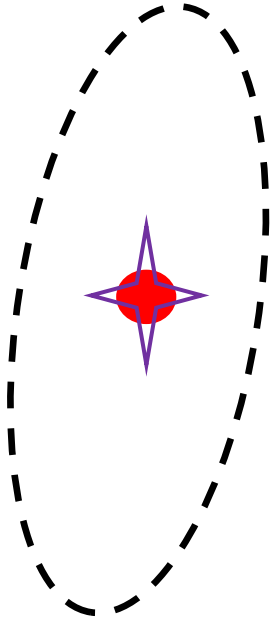
(1) pointed obs. with WXT for 1-2 orbits



(2) a sequence of snapshots with FXT of 5 min each



(3) deep follow-up obs with FXT for promising candidates



Synergy with MAXI, XRISM

- MAXI
  - Sensitivity is better in EP
  - Sky coverage is better in MAXI
  - Complementary energy band: MAXI 2-30 keV vs. EP 0.5-4 keV
  - Monitoring soft-to-hard X-ray behaviors of
    - Galactic X-ray objects
    - Top-bright extragalactic sources

- XRISM
  - Spectroscopic observations of EP transients
  - XRISM ToO time scale ~ 1 day
    - Tidal disruption events
    - Ultraluminous X-ray sources

Summary

- Einstein Probe (EP) is the Chinese X-ray satellite mission for soft X-ray survey, launched in 2022
- International collaboration mission with ESA, MPE, (CNES)
- EP WXT will achieve the 10 times better sensitivity than the past surveys, using Lobster-eye optics and CMOS image sensors.
- Key devices: Lobster-eye mirrors and CMOS sensors are manufactured in Chinese companies

- Think good science collaborations, MAXI, XRISM