All Sky Monitors

—— RXTE / MAXI / Einstein Probe(EP)

Restless universe

Rui Huang

Thanks Prof. Feng & Prof. Cui

outline

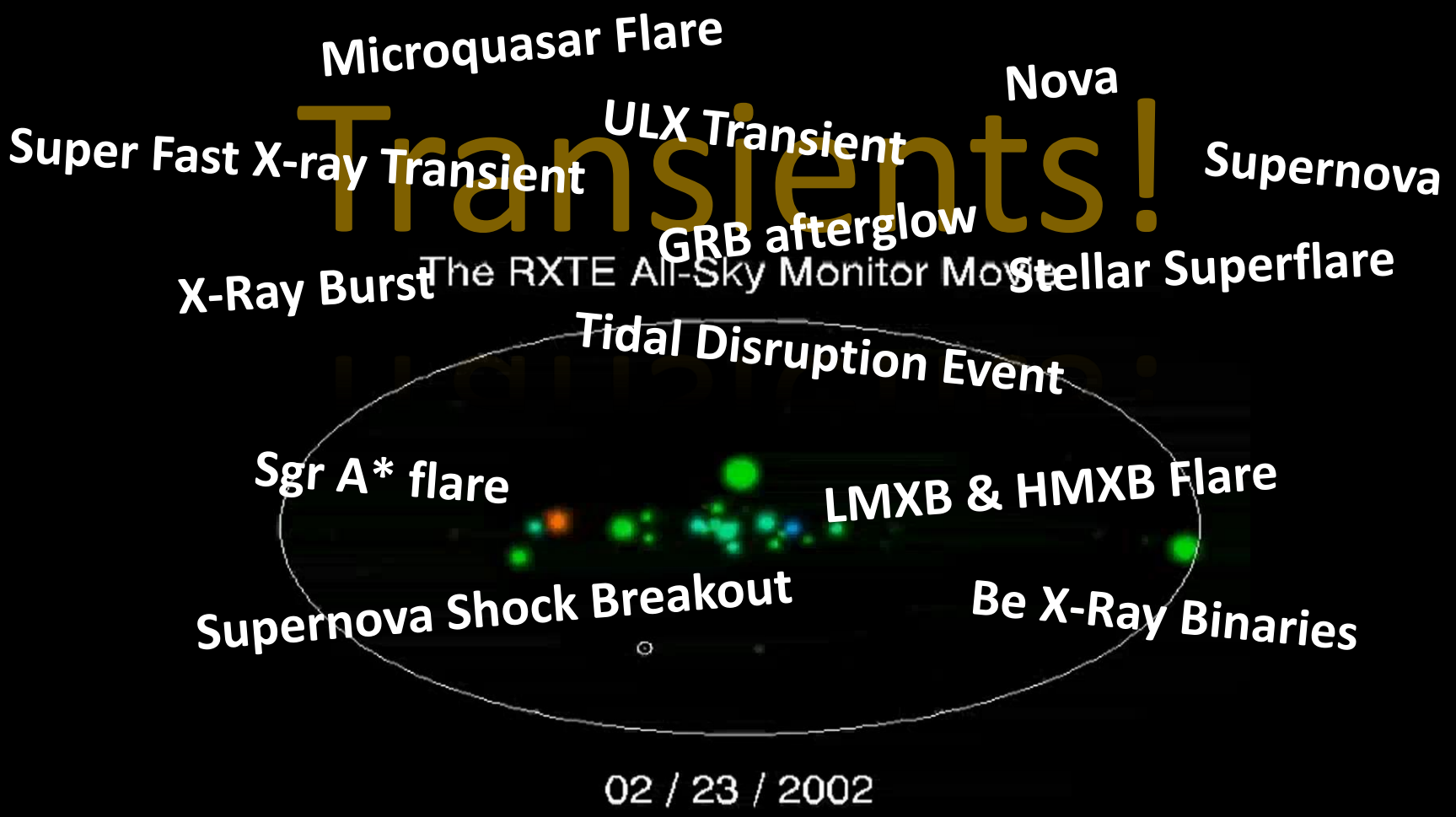
- Why ASM?

- ASM/RXTE
- MAXI
- Einstein Probe

- Summary

Why we need all sky monitor ?

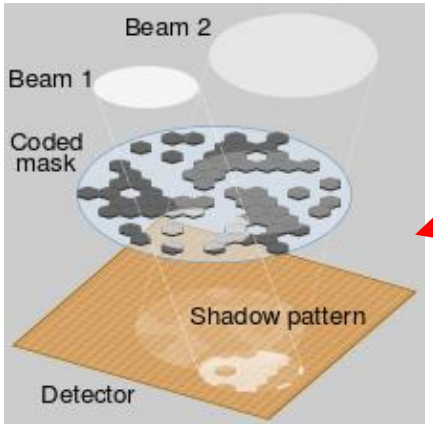
The sky is rich in transients of many types

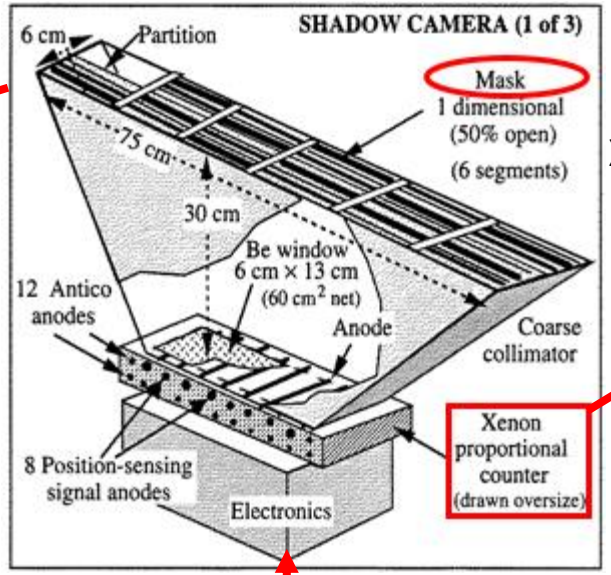


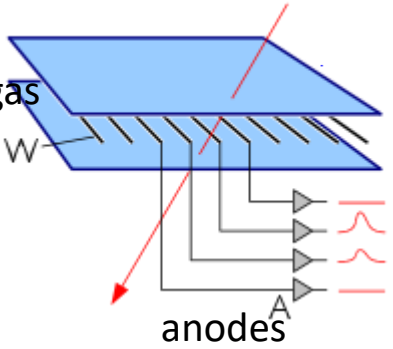
USA

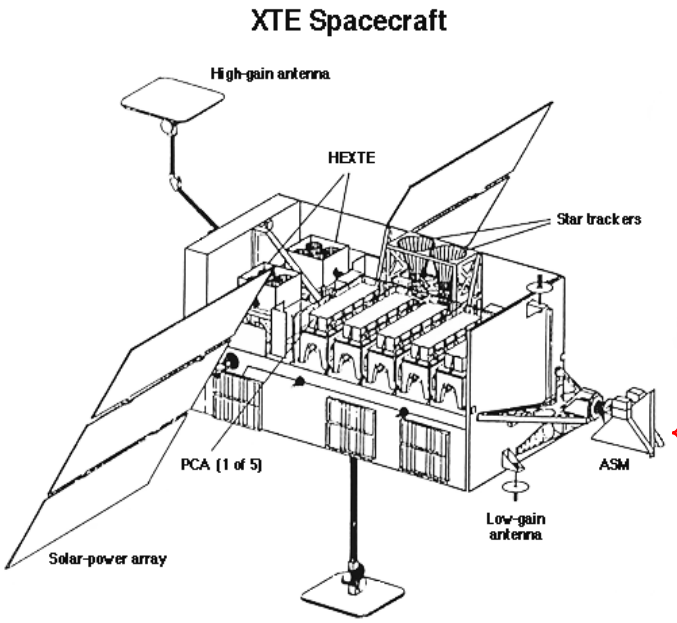
ASM/RXTE 1995/12/30-2012/01/03

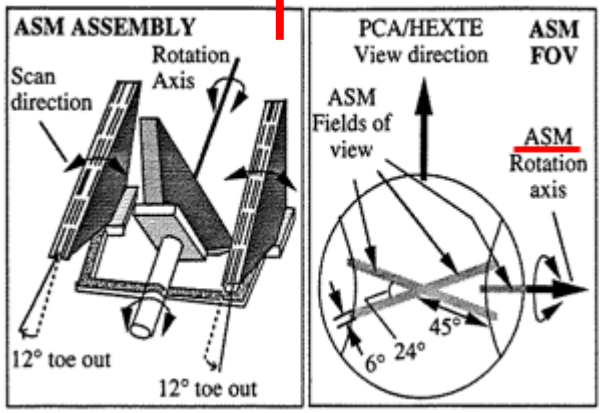
All Sky Monitor/Rossi X-Ray Timing Explorer











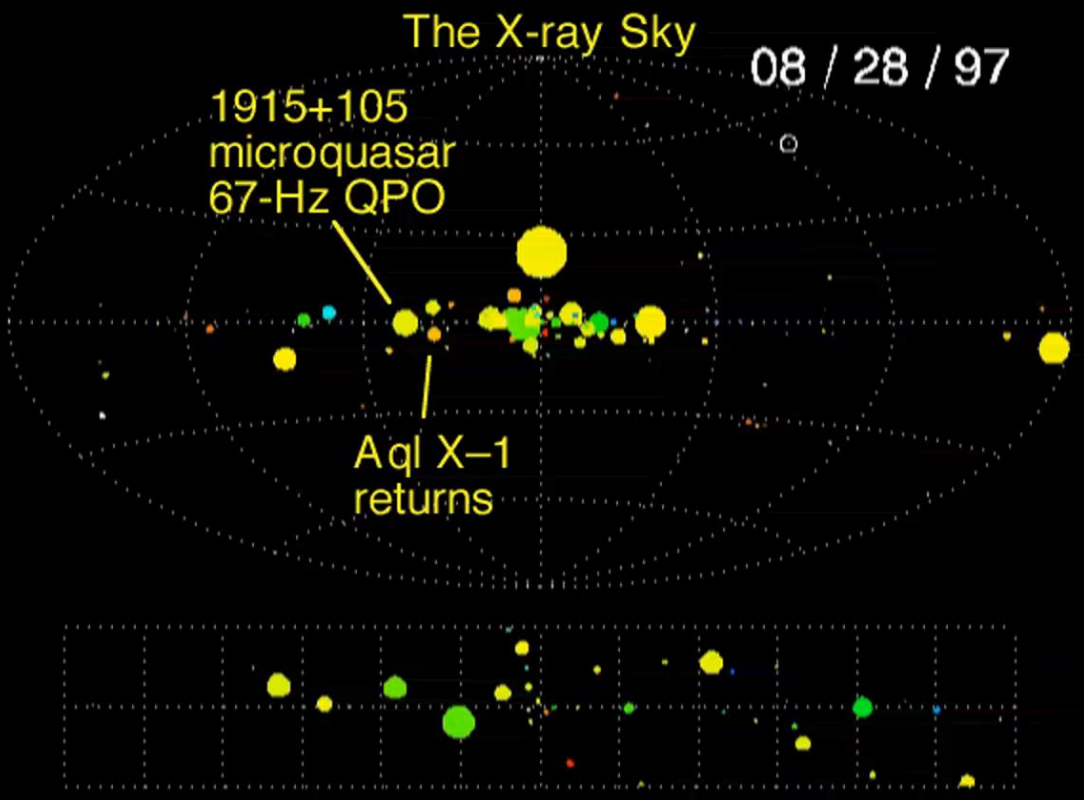
- 3 Scanning Shadow Camera
- Coded Mask
- FOV : 6° x 90°
- Xenon proportional counter (charge-division technique)
- 2-10 keV
- 90 cm2
- 30 mCrab

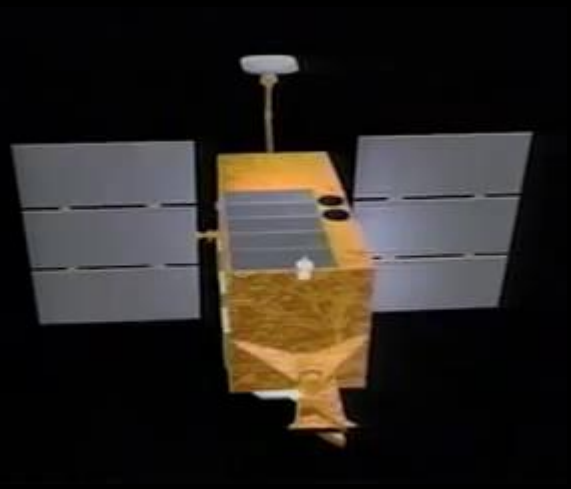
ALAN M. LEVINE, et al. APJ.1996

ASM/RXTE

1995/12/30-2012/01/03

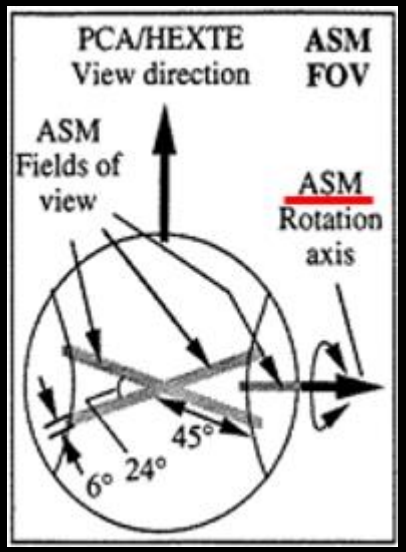
All Sky Monitor/Rossi X-Ray Timing Explorer





orbit: ~500km ~90 min

exposed for 90s in one direction



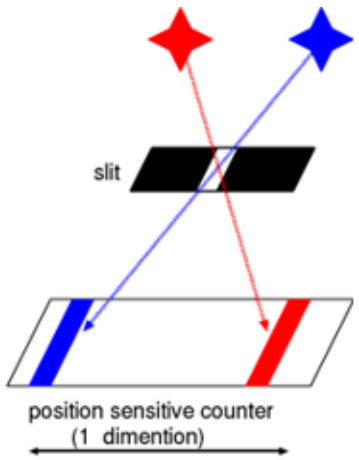
ALAN M. LEVINE, et al. APJ. 1996

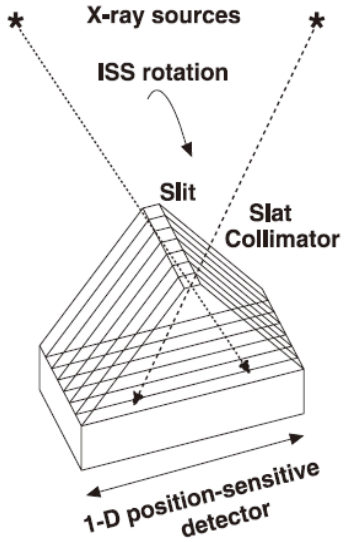
Japan

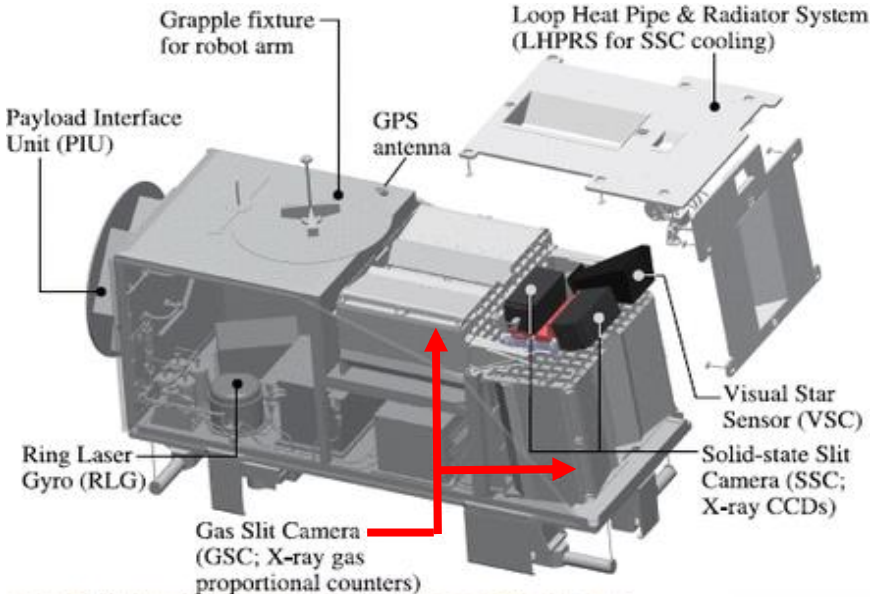
Monitor of All-Sky X-ray Image

MAXI 2009/07/16-Present

onboard ISS
(International Space Station)







Masaru MATSUOKA, et al. 2009

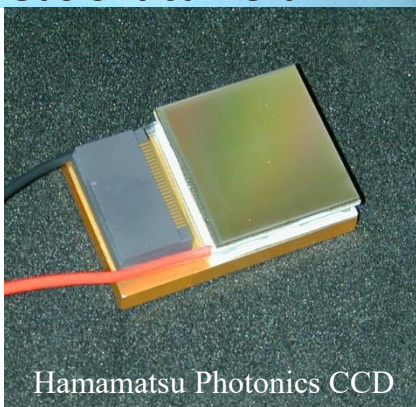
Gas Slit Camera

- Xe + CO_2(1%)
- 2-30 keV
- 5350 cm^2
- 1.5° x 160°
- 18% @5.9keV

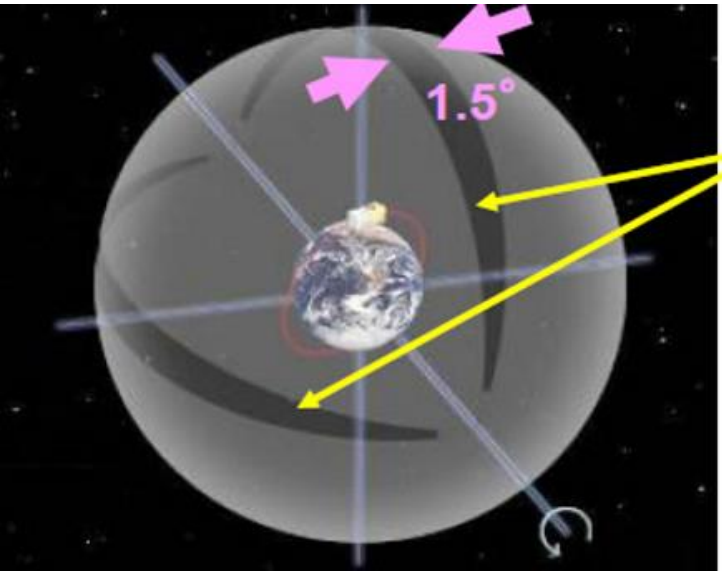
Principle of the MAXI Slit Camera; it consists of slit & slat collimators and a one-dimensional position sensitive X-ray detector.

Solid-state Slit Camera

- CCD
- 0.5-12 keV
- 200 cm^2
- 1.5° x 90°
- 3% @5.9keV

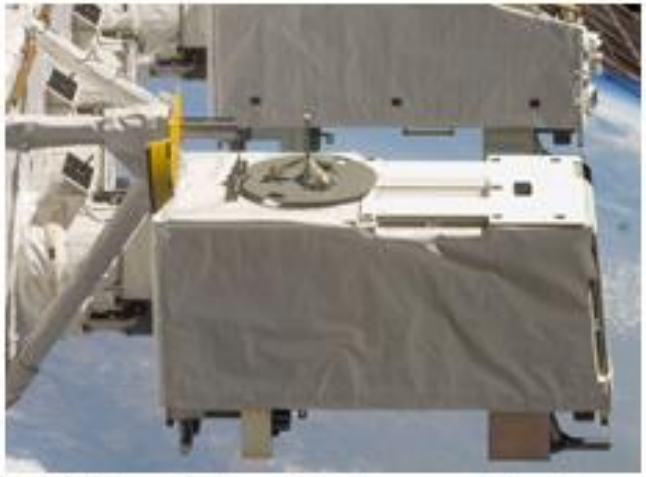


- Objects located along a great circle stay for 45 s in the FOV of the MAXI cameras, where the time of stay is the shortest in the MAXI normal direction (for a great circle).

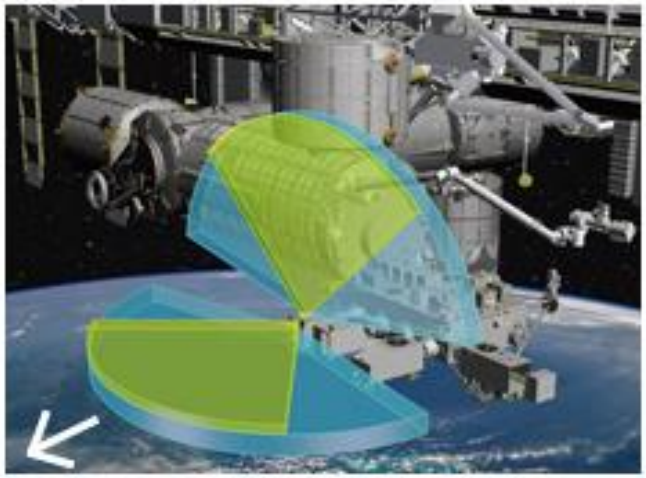


View of GSC
(1.5°X 160° arch)

Observations in two directions; in the moving direction of the ISS and toward the zenith



MAXI installed on the Exposed Facility of Kibo (Courtesy of NASA)



MAXI's vision. Blue shows the view through the GSC camera, and yellow shows the view through the SSC camera. The arrow indicates the direction of the ISS's flight.

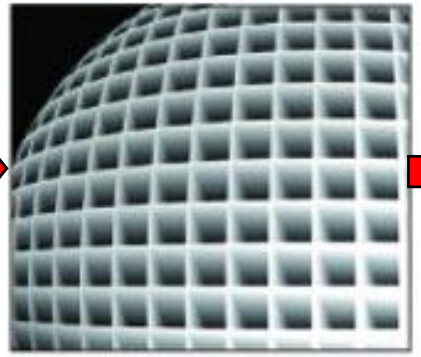
China

Einstein Probe (EP)

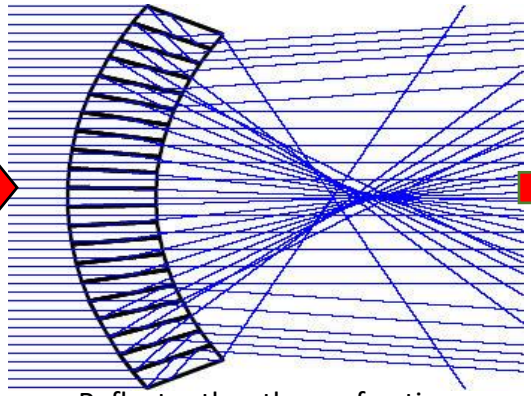
May be launched in 2022

WXT: Wide Field X-ray Telescope
FXT: follow up X-ray telescope

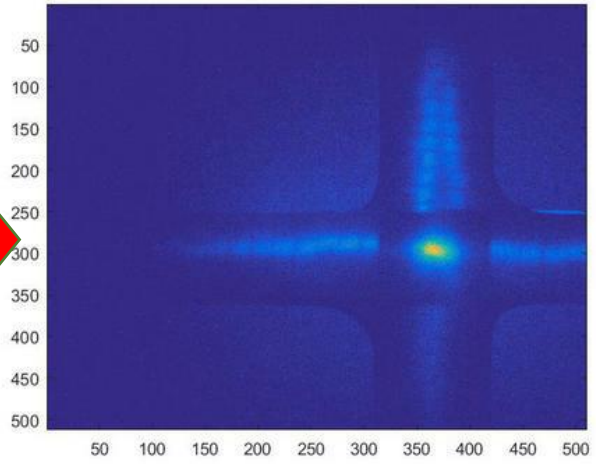
I'm going into space!



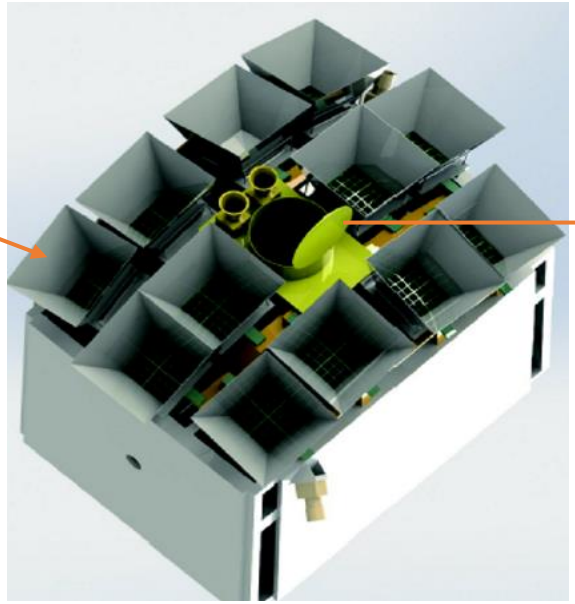
micro-pore



Reflect rather than refracting



- **WXT** (Wide Field X-ray Telescope)
- **lobster-eye**
- **60° X 60° FOV**
- **5’**
- **CMOS** (Complementary Metal Oxide Semiconductor)
- **0.5-4 keV**
- **170 eV @1keV**
- **0.3 mCrab**



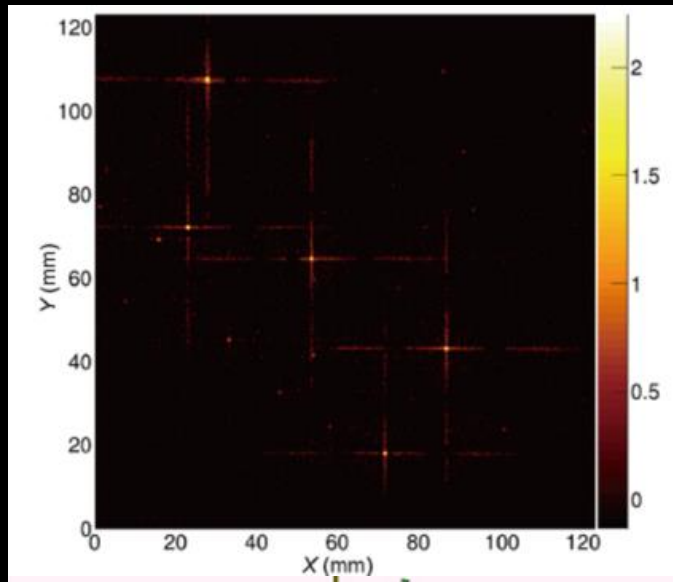
possible design
Weimin Yuan, et al. 2018

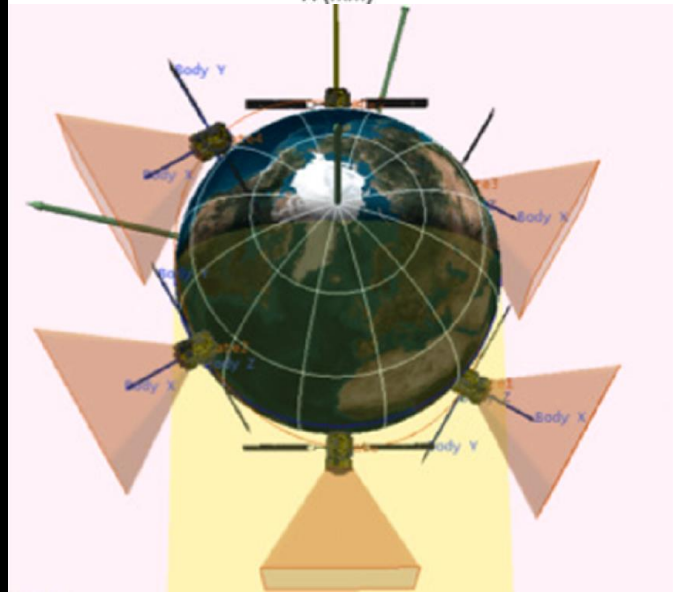
First image from the prototype of micro-pore (MPO) lobster-eye optics

- **FXT** (follow up X-ray telescope)
- **Wolter I**
- **1° X 1° FOV**
- **< 2’’**
- **CCD**
- **0.3-8 keV**
- **170 eV @1keV**
- **0.1 mCrab**

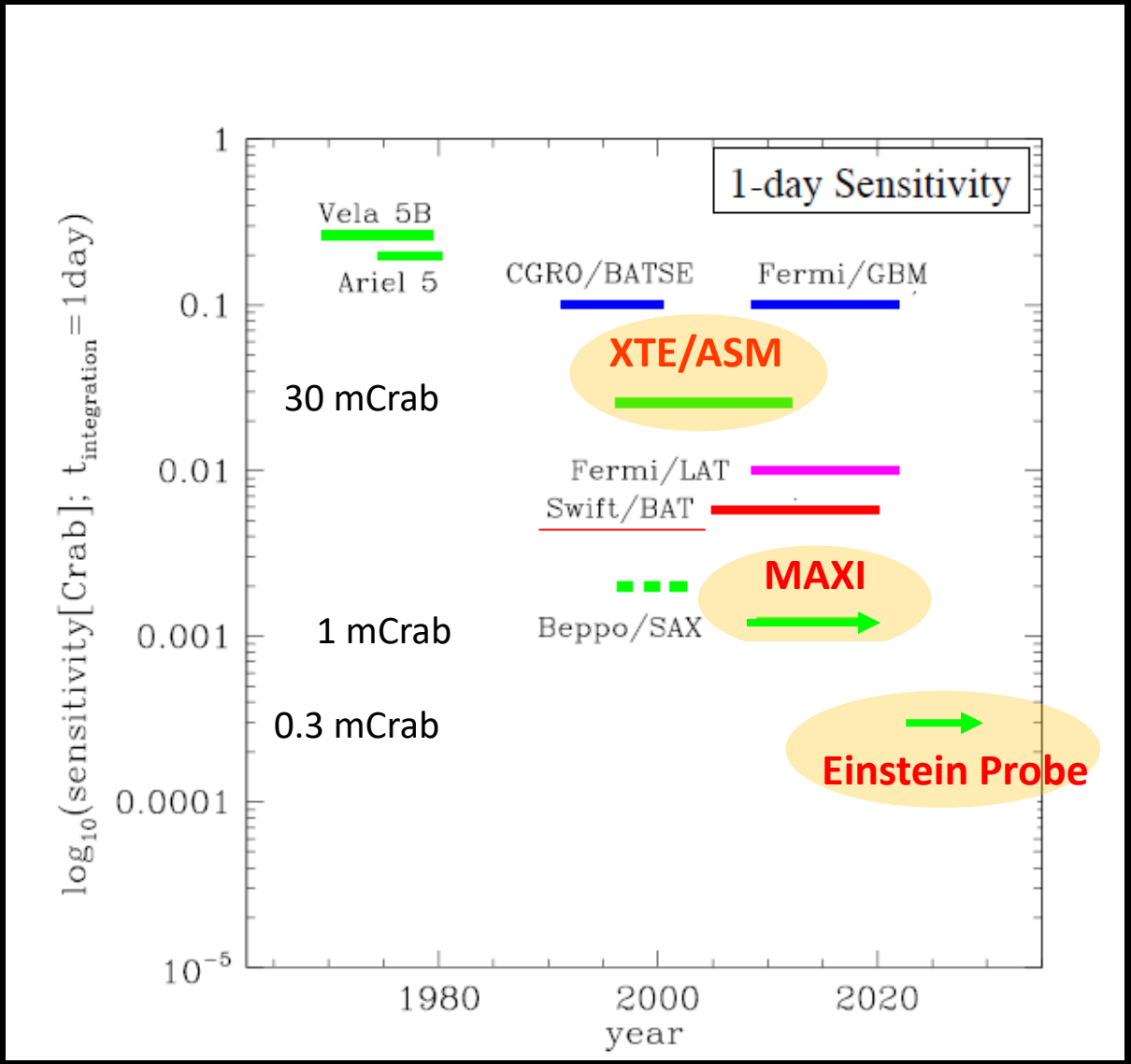
strategy of observation

- 97 min per orbits
- 20 min one direction.
- Only the night sky in the opposite direction of the sun is monitored.
- Only half sky is monitored in one day.





Sensitivity



Sensitivity represent the dimmest sources that the telescope can observe.

$$R = \frac{\sigma\sqrt{BAt}}{\eta A t} = \frac{\sigma}{\eta}\sqrt{\frac{B}{At}}$$

Fov:

3 X 6° X 90° 2-10 keV

2 X (1.5° X 160° + 1.5° X 90°) 0.5-30 keV

60° X 60° 0.5 - 4keV

from Neil Gehrels's report in ISSI Beijing Dynamic Universe Forum 2014

In the photon energy range from 2 to 10 keV,
1 Crab equals $2.4 \cdot 10^{-8}$ erg cm^{-2} s^{-1} = 15 keV cm^{-2} s^{-1}
= $2.4 \cdot 10^{-11}$ W m^{-2}

Summary

- All Sky Monitor is necessary!

- ASM/RXTE -past
  - shadow camera
  - 30 mCrab 1620 square degree
- MAXI -present
  - slit camera
  - 1 mCrab 750 square degree
- WXT/EP -future
  - lobster eye better sensitivity and larger FOV
  - 0.3 mCrab 3600 square degree

- Time domain astronomy

Summary

	ASM/RXTE	MAXI(GSC)	MAXI(SSC)	EP(WXT) wide field x-ray telescope	EP(FXT) follow up telescope
Time	1995/12/30-2012/01/03 (about 16 years)	2009/7/16-present (almost 9 years)	-	maybe launch 2022.plan 3y ,goal 5 year	
	3 segments? detectors there shadow cameras	Gas Slit Camera	Solid-state Slit Camera	12 module(6X6 MPO,300 square degrees and per module)	1
optical system 1	Coded Mask	Slat Collimator	Slat Collimator	lobster (Micro-pore Optics)	Wolter I (1.6 m focal length)
detector	Xenon proportional counter (charge-division technique)	two proportional counter(Xe + CO21%) (1-D position-sensitive detector) ;	CCDs sum up to one dimension	CMOS(4 K X 4 K,6 cm X 6 cm) 2X2 CMOS per module	pn-CCD maybe
detector area	90 square cm	5350	200cm2	1728 cm2 focal plane ~3 cm2 (effective area@ 1keV)	>=120 cm2 (effective area @1keV)
(detector resolution)		1 mm	0.025 mm		
Fov	6 x 90 square degrees	1.5 x 160 square degrees	1.5 x 90 square degrees	60 X 60	1 X 1 ? 38'
Spatial resolution	3 x 15 arcmin	0.1 degree	0.1 degree	5 arcmin	<2'
sensitivity	20 mCrab in what condition? how long Time?	2m Crab limit for 1 day		one level?	
energy range	2-10keV	2-30 KeV	0.5-12 keV	0.5 - 4keV	0.3 - 8 keV
Energy resolution		18%(5.9keV);	<=150eV(5.9keV) 3%?	170 eV @ 1keV	170 eV @ 1keV
Time resolution	90s inteegration time,1/8 s time bins also available	0.1ms ;	5.8 s		
Cost	350 million dollar		-	1 billion RMB	
Strategy of observation	fix at one direction for 90s. 80% of the sky every 90 minutes	• rotate with ISS • procession of the orbit ensure the courage of all sky	-	• 20 min one direction. • Only the night sky in the opposite direction of the sun is monitored.so only half sky monitored one day. • 5h for 3 times orbits cover half of sky	
orbit	90 minutes , about 500Km	about 92 minutes with ISS	-	about 97min,	
	satellite	International Space Station	-	Satellite	
		GSC: 160kg 520 kg in total		WXT:17kg X 12	100kg