Insight-HXMT observations in Multiwavelength era

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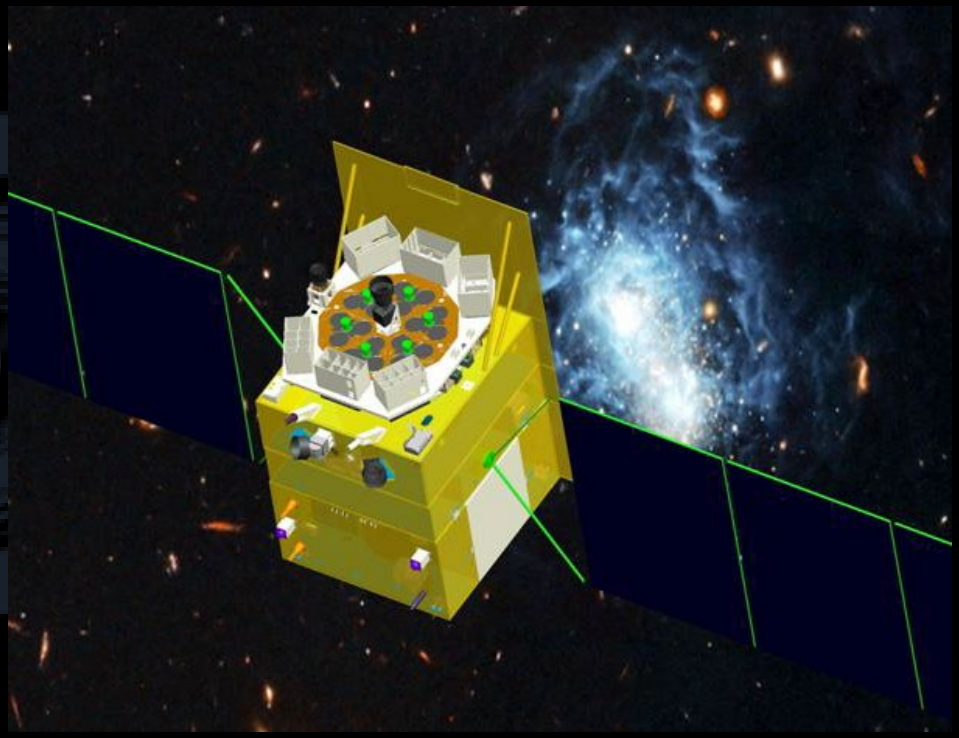
Outline

- Mission and payload
- Performed observations
- Preliminary results
- Summary

Mission and payload

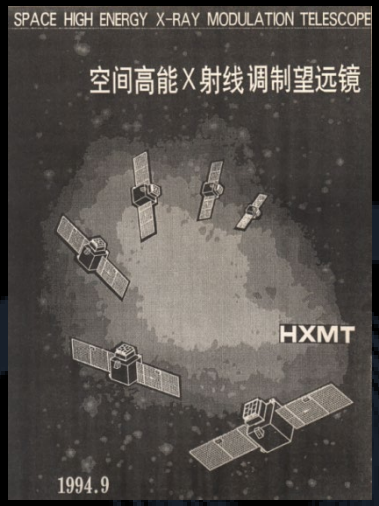
Hard X-ray Modulation Telescope (HXMT) satellite

- China's 1st X-ray astronomy satellite
- Selected in 2011
- Total weight ~2500 kg
- Cir. Orbit 550 km, incl. 43°
- Pointed, scanning and GRB modes
- Designed lifetime 4 yrs
- Launched on June 15th, 2017
- Dubbed "*Insight*"

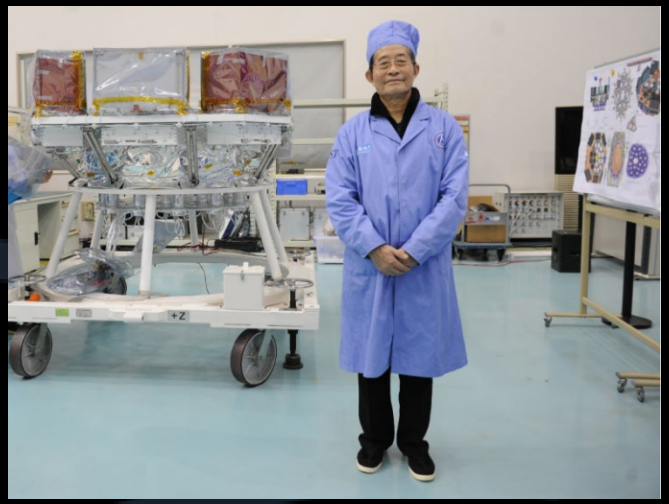


History of 慧眼Insight-HXMT

1970-80s balloon flight



1994 first proposal，2011 funded



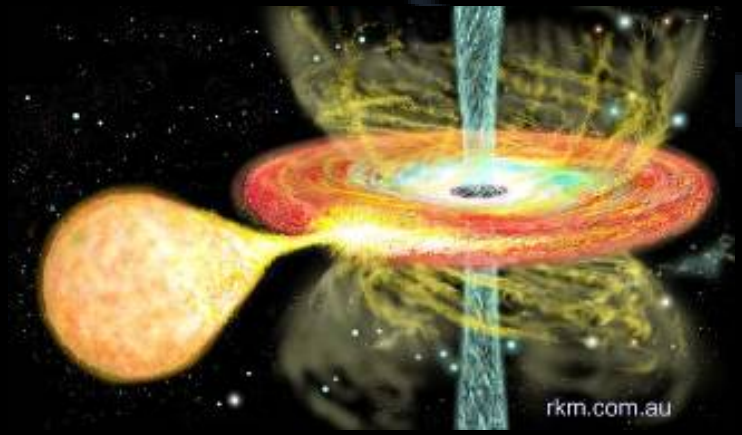
李惕碚院士Prof. Ti-Pei Li

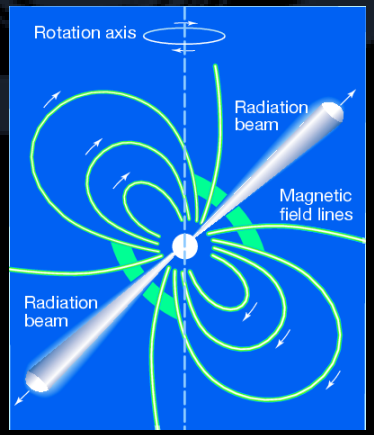
In honor of
何泽慧 Ho Zah-wei (1914-2011)
“慧眼” *Insight*

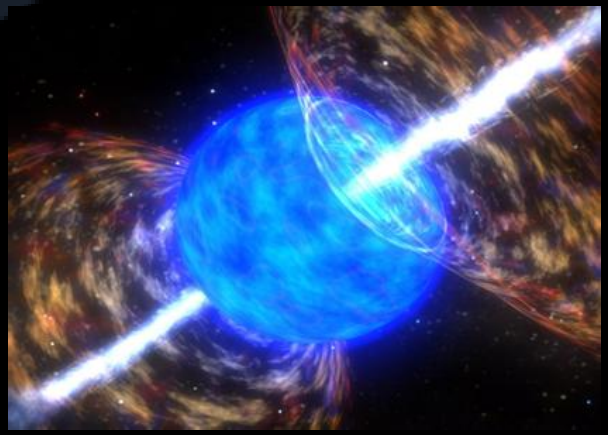
2017.6.15 Launched in Jiuquan, China

Core sciences

- ✓ Galactic plane scan and monitor survey for more weak & short transient sources in very wide energy band (1-250 keV)
- ✓ Pointed observations: High statistics study of bright sources and Long-term high cadence monitoring of XRB outbursts
- ✓ Multi-wavelength Observations with other telescopes
- ✓ GRBs and GW EM, FRB, etc.



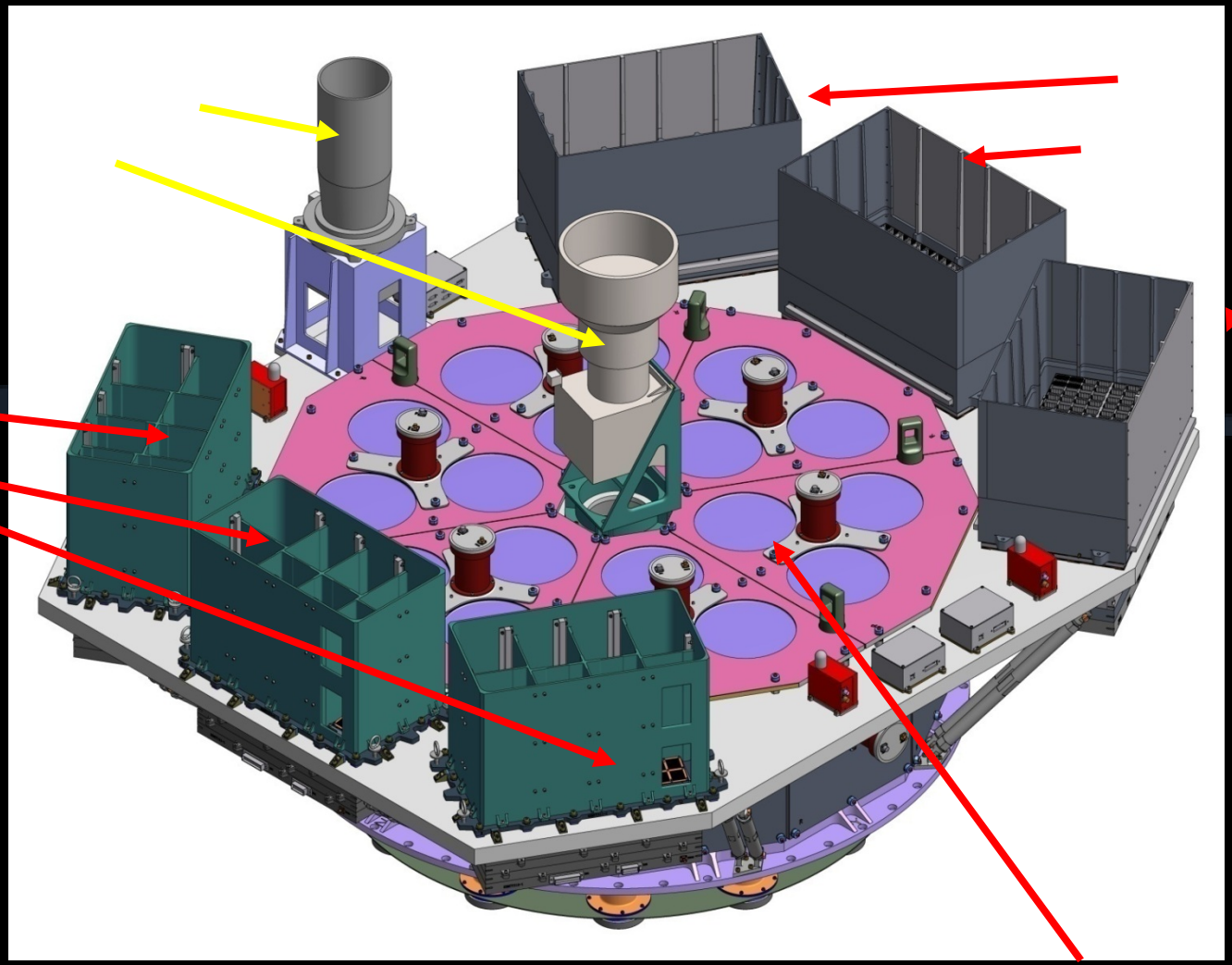




Science payloads

Star tracker

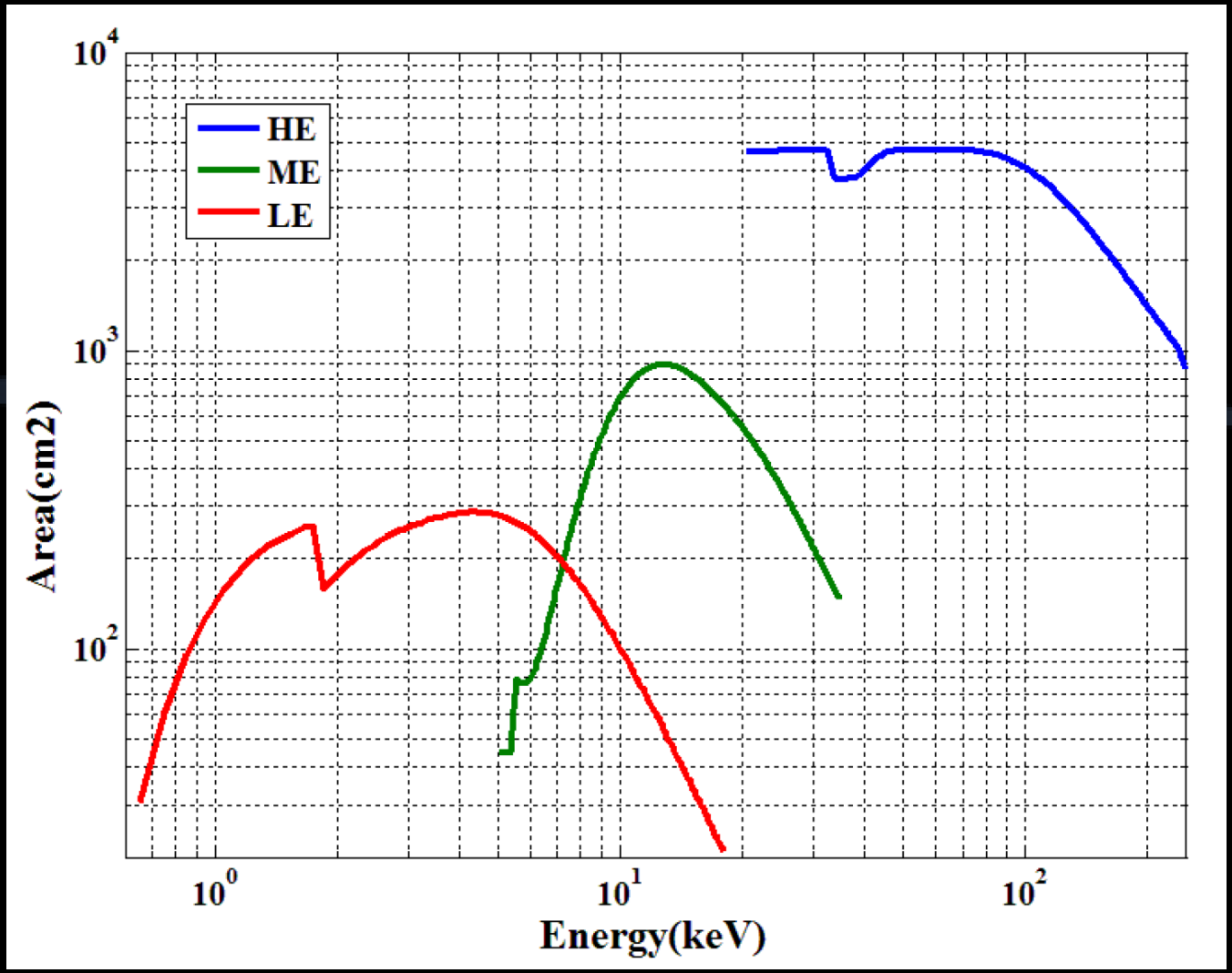
LE:SCD,1-15 keV, 384 cm^2



ME:Si-PIN,5-30 keV, 952 cm^2

HE: NaI/CsI, 20-250 keV, 5000 cm^2

Effective area

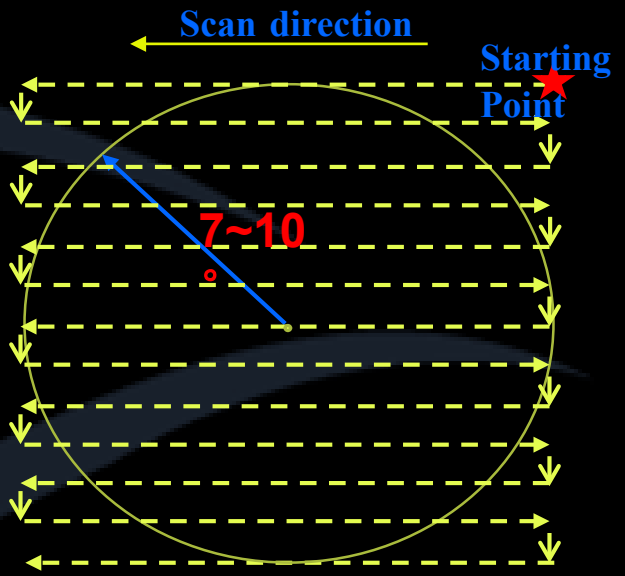


Comparison with other hard X-ray telescopes

Insight-HXMT		RXTE	INTEGRAL/IBIS	SWIFT	NuSTAR
Energy Band (keV)	LE: 1-15 ME: 5-30 HE: 20-250	PCA: 2-60 HEXTE: 15-250	15-10000	XRT: 0.5-10 BAT: 10-150	3-79
Detection Area (cm^2)	LE: 384 ME: 950 HE: 5000	PCA: 6000 HEXTE: 1600	2600	XRT: 110 BAT: 5200	847 @ 9 keV 60 @ 78 keV
Energy Resolution (keV)	0.15@ 6 keV 2.5@20 keV 10@60 keV	1.2@6keV 10@60 keV	8@ 100 keV	0.15 @ 6 keV 3.3 @ 60 keV	0.9 @ 60 keV
Time Resolution (ms)	LE: 1 ME: 0.18 HE: 0.012	PCA: 0.001 HEXTE: 0.006	0.06	XRT: 0.14, 2.2,2500 BAT: 0.1	0.1

Observing Modes

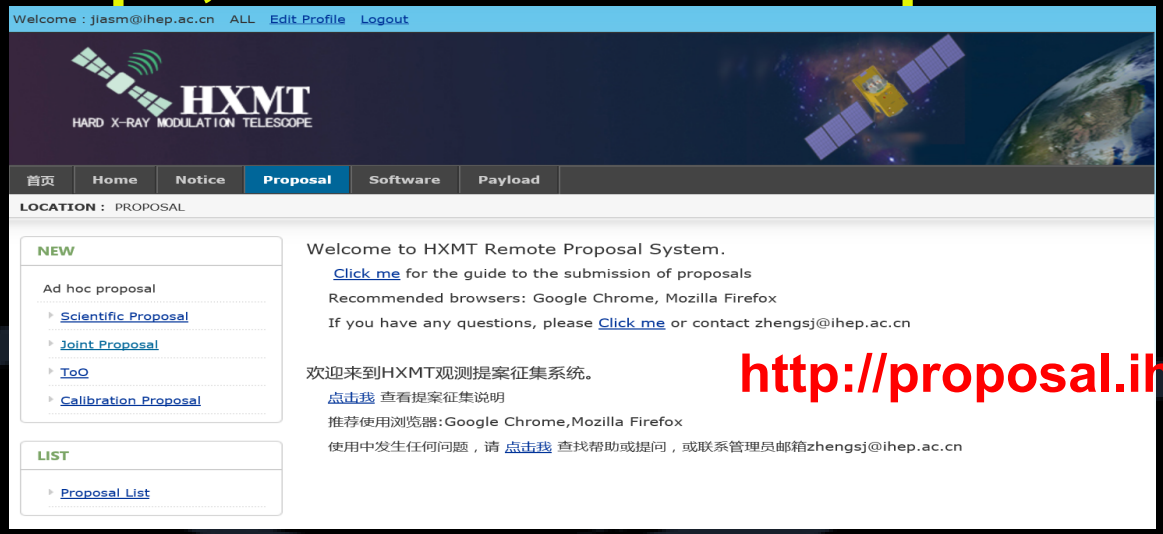
- **Pointed Observation:** Observing time: 96 mins~20 days
  - Spectrum
  - Variable properties
- **Small Area Scan:**
  - A square area of 14*14~20*20
    - Scan radius: 7~10 degree
    - Scan velocity: 0.01, 0.03, 0.06 deg/s
    - Scan step: 0.1~1 degree
    - Scan duration: 2 hours ~ 5 days
  - Galactic Plane Scan
  - Other interesting small areas



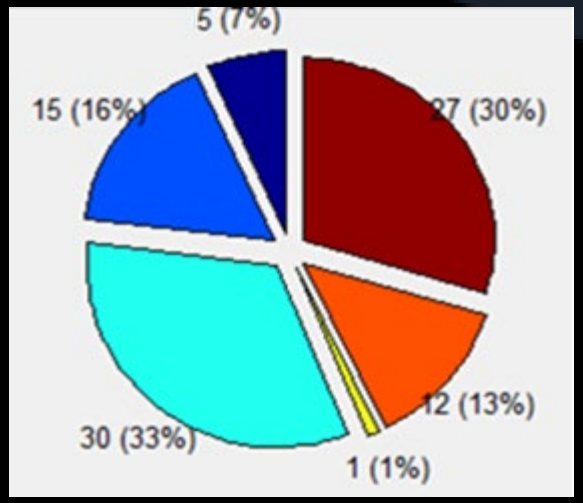
- **GRB Mode:** designed and implemented for HE
  - In this mode, the high voltage of the photo-multiplier tube (PMT) is reduced, so that the measured energy range of CsI goes up to 0.2-3 MeV.
  - **HE:** unique high-energy gamma-ray telescope to monitor the entire GW localization area and the optical counterpart, with the large collection area (~1000 cm^2) and microsecond time resolution.

Proposals of AO01

Aug.-Sept., 2016 : Call for Proposals (AO01)



http://proposal.ihep.ac.cn



Total: 90 Proposals

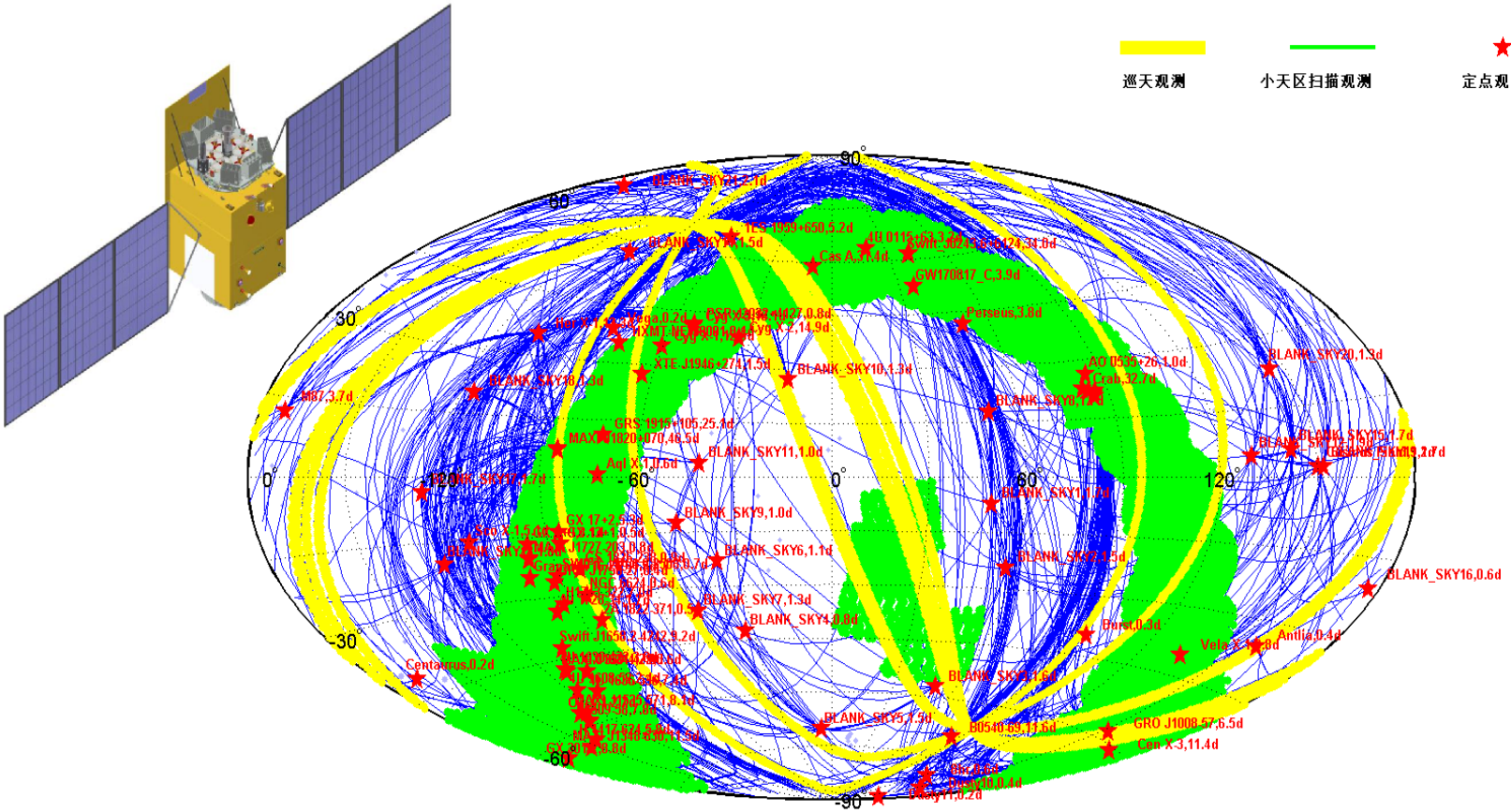
- Galactic Plane Survey
- High Cadence Observation of BH and NS systems
- High Statistics Observation of BH and NS systems
- Synergy Observation with international telescopes
- Multi-wavelength Coordinated and Follow-up OBS
- Others

Proposals of AO 02

Announcement: 2019 1.1
Deadline: 2019 3.15
http://proposal.ihep.ac.cn/proposal/index.jspx
Total proposal number : 35
Core program : 3
ToO : 6
Calibration : 1
Guest observer : 23
Multivelength : 2
Total exposure: 12 Ms, core 60%, guest 40%

Performed observations

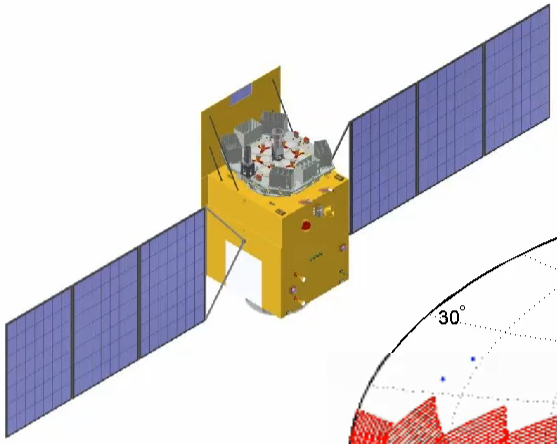
	Mode	Type	Source Name	次数	观测时
1	Point	Supernova remnants	Cas A	9	530
2		Pulsar	Crab	86	1530
3			PSR B0540-69	7	250
4			PSR B1509-58	12	310
5		BH Binary	Cyg X-1	12	270
6			Granat 1716-249	2	250
7			GRS 1915+105	24	720
8			GX 339-4	1	100
9			H 1743-322	15	180
10			MAXI J1535-571	18	430
11			MAXI J1543-564	1	80
12			MAXI J1820+070	61	1360
13			Swift J1658.2-4242	23	470
14		Extra-galactic	1ES 1959+650	25	255
15			Perseus	2	200
16			M87	4	180
17			Cosmos Field	4	80
18	Point		Aql X-1	3	30
19			Cen X-3	14	400
20			Cir X-1	6	100
21			Cyg X-2	22	540
22			Cyg X-3	15	390
23			GRO J1008-57	11	340
24			GRO1750-27	1	15
25			GS 1826-238	1	40
26			GX 301-2	15	400
27			GX9+9	4	80
28			GX 13+1	1	30
29			GX 17+2	9	210
30		NS Binary	Her X-1	12	380
31			Sco X-1	6	180
32			Vela X-1	1	120
33			2A 1822-371	1	30
34			4U 1728-34	4	90
35			4U 0115+63	11	150
36			4U1636-536	19	200
37			PSR J2032+4127	4	40
38			NGC 6624	1	30
39			H 1417-624	21	210
40			IGR J16328-4726	2	20
41			Swift J1756.9-2508	1	40
42			Swift J0243.6+6124	97	1200
43		BlankSky	21	84	840
44	SAS	Crab Area		9	550
45		Galactic Plane	22 regions	324	3600

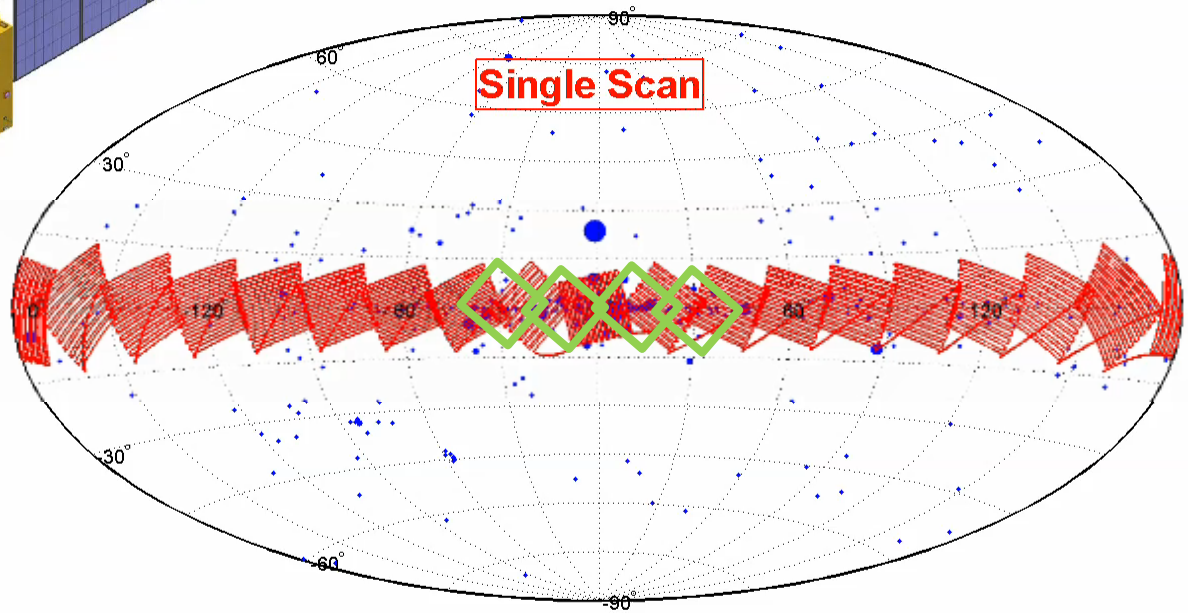


Red stars: pointed observation
Green regions: small area scan

Preliminary results

Galactic Plane Scan

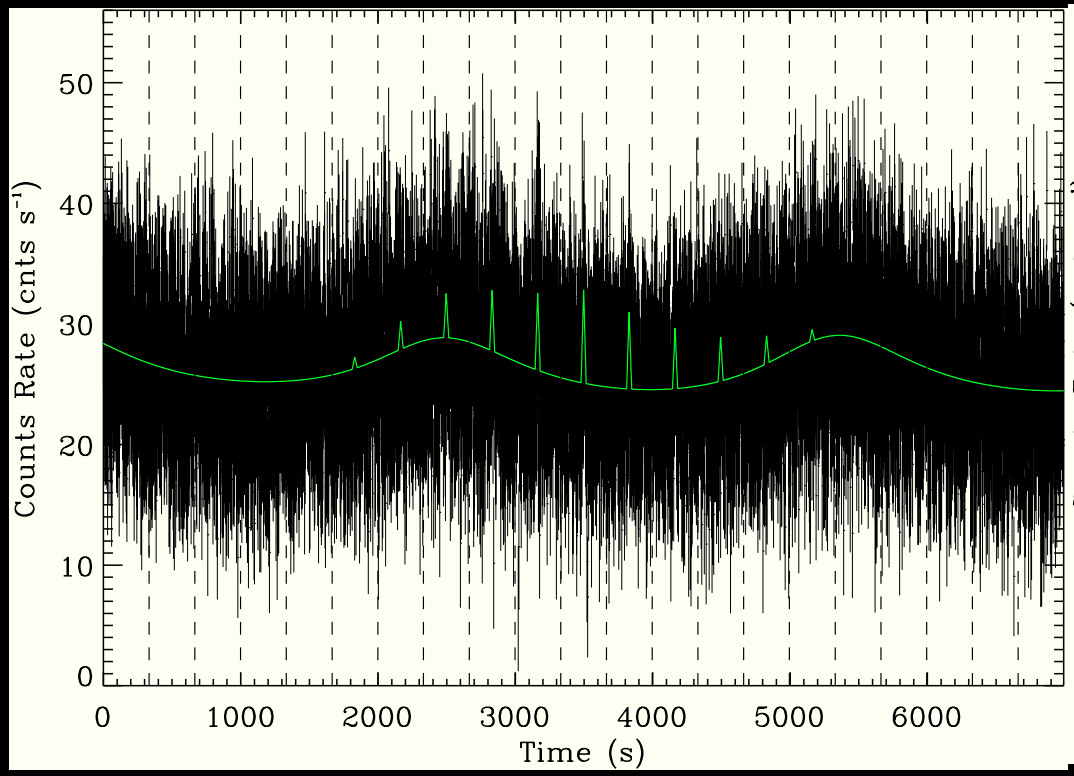


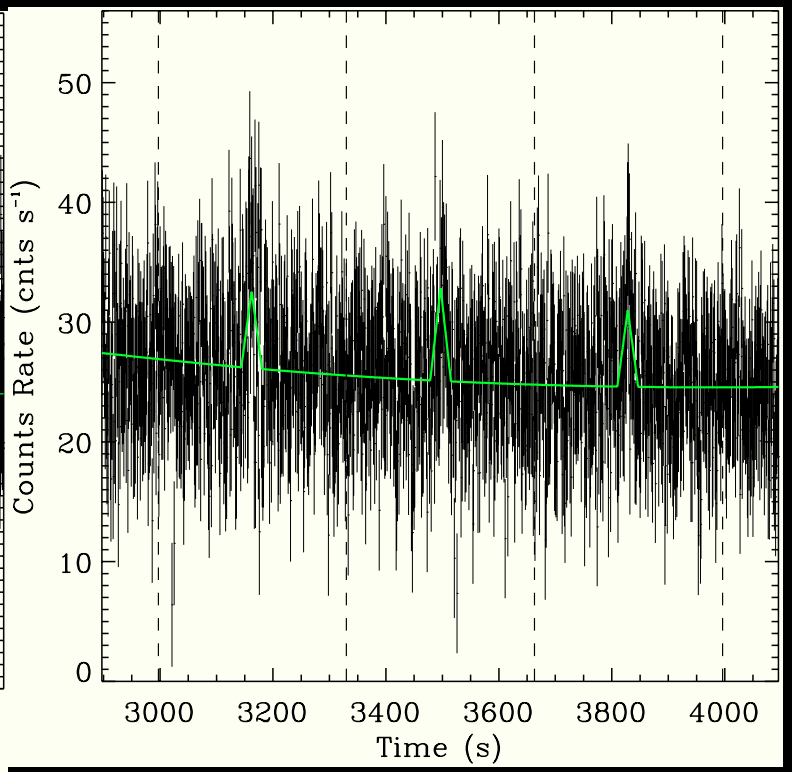


Galactic Plane: (20°*20°)*18 + (20°*20°)*4

- 11 center regions: 90 times/year (-60°~60°)
- 11 outer regions: 10 times/year

Point Spread Function fitting: simulation

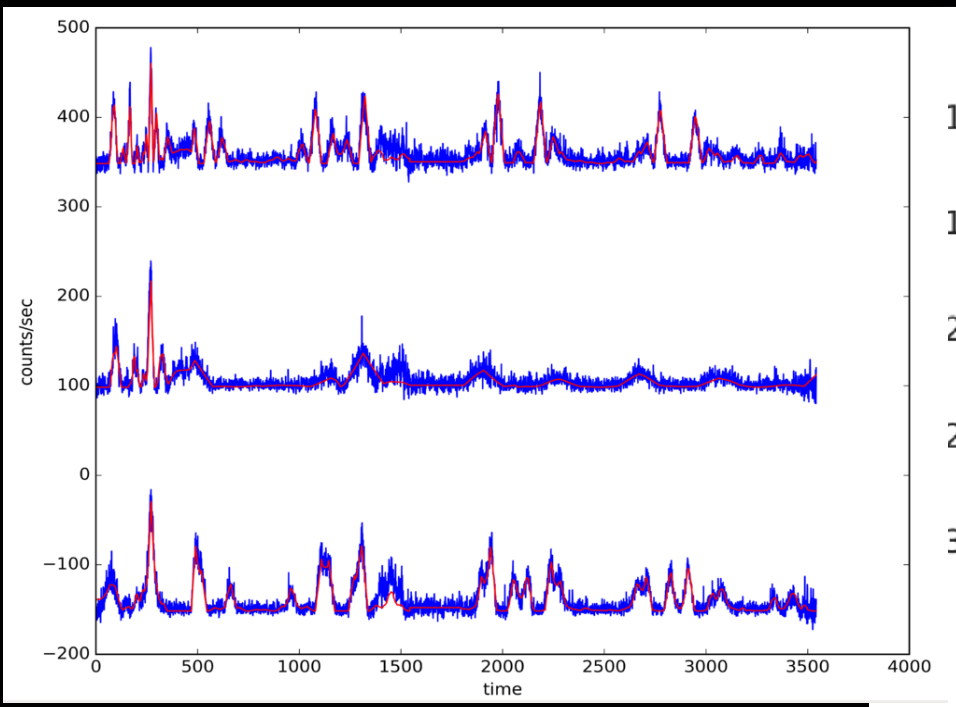


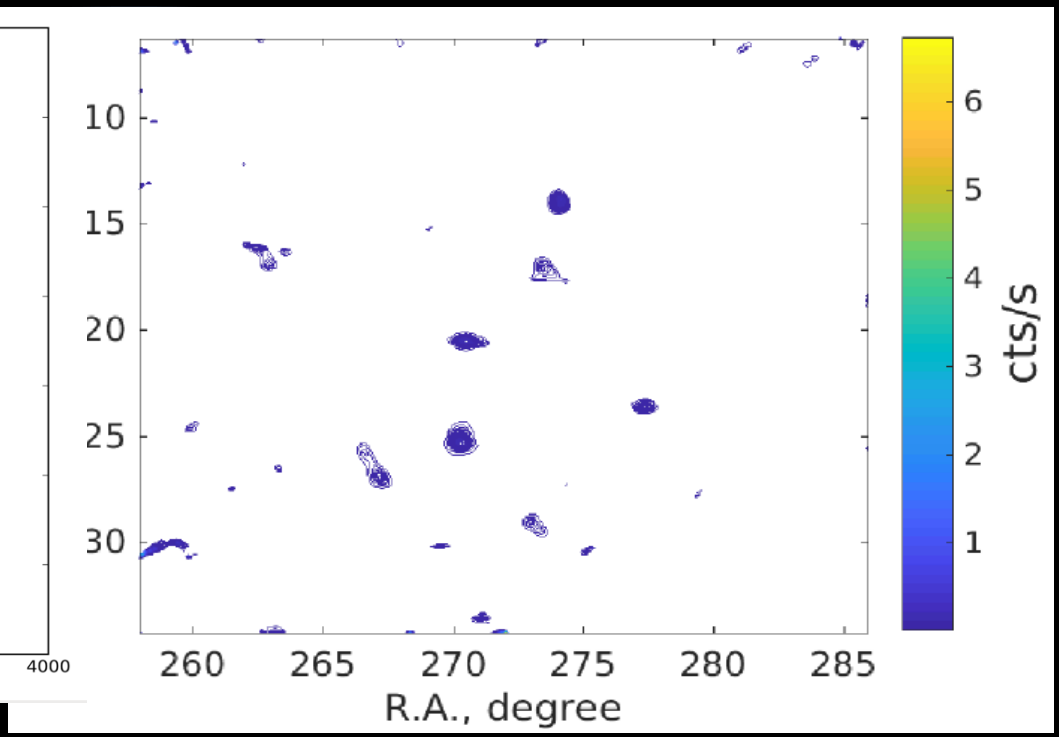


- ✓A group of peaks due to one source
- ✓Combine all FOVs to determine its position and flux

Observed light curve

July 16 on Galactic center (LE 1-6 keV)



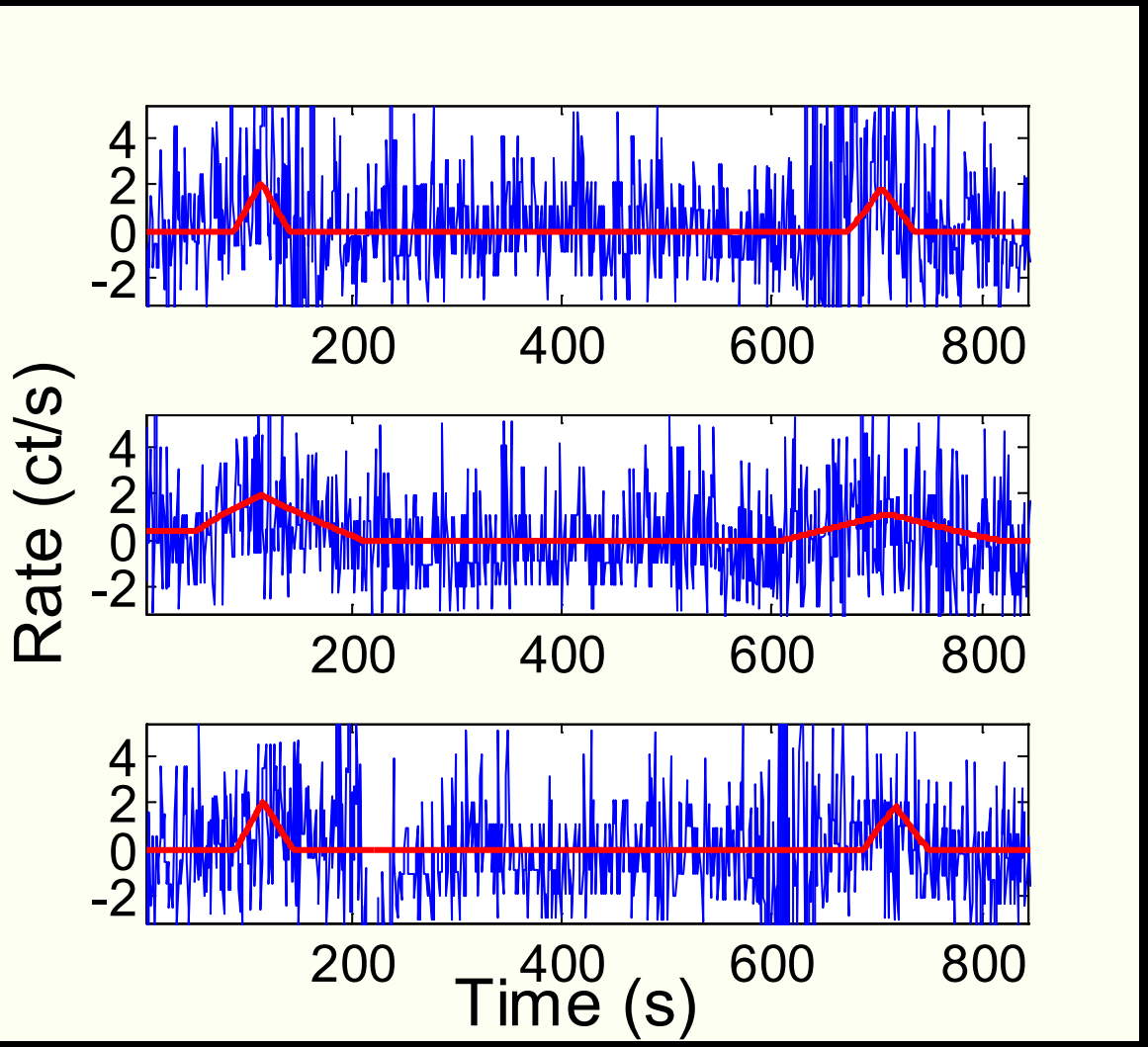


Direct Demodulation Method
(Li & Wu 1993)

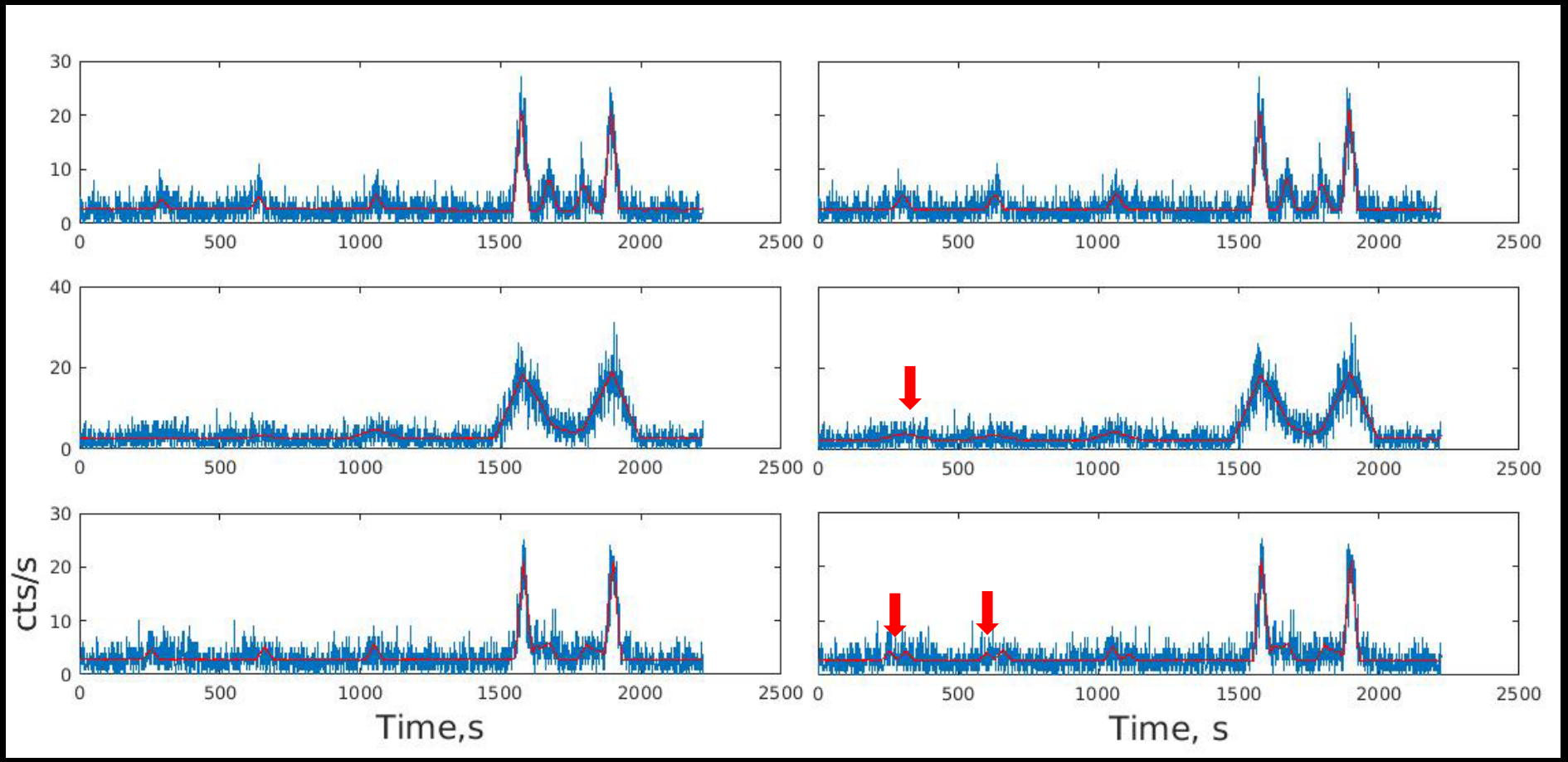
G21.5–0.9 (PWN)

- ✓Not in MAXI catalog
- ✓Detected by Insight at 8σ

MAXI sensitivity:
one orbit 130 mCrab (5σ)
one day 20 mCrab (5σ)



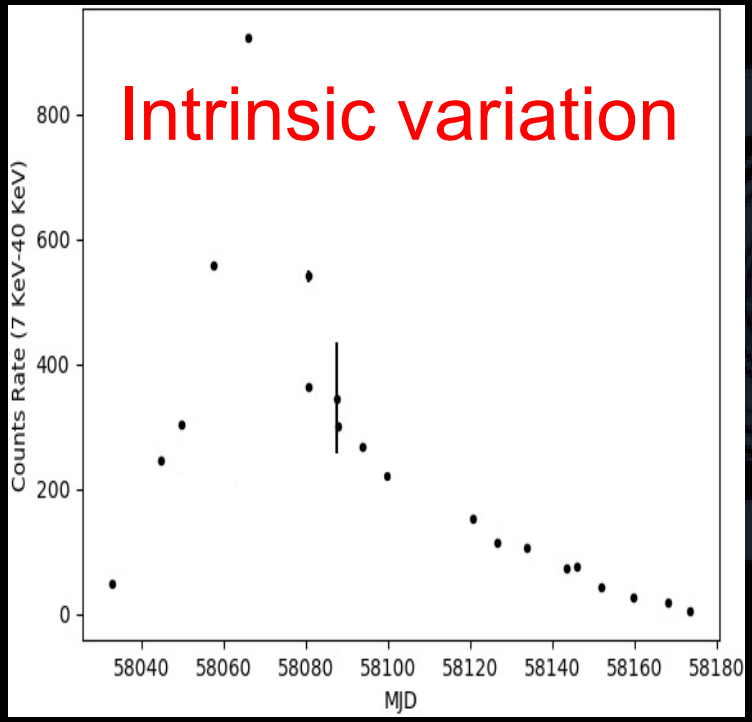
Possible new source detected in Galactic survey

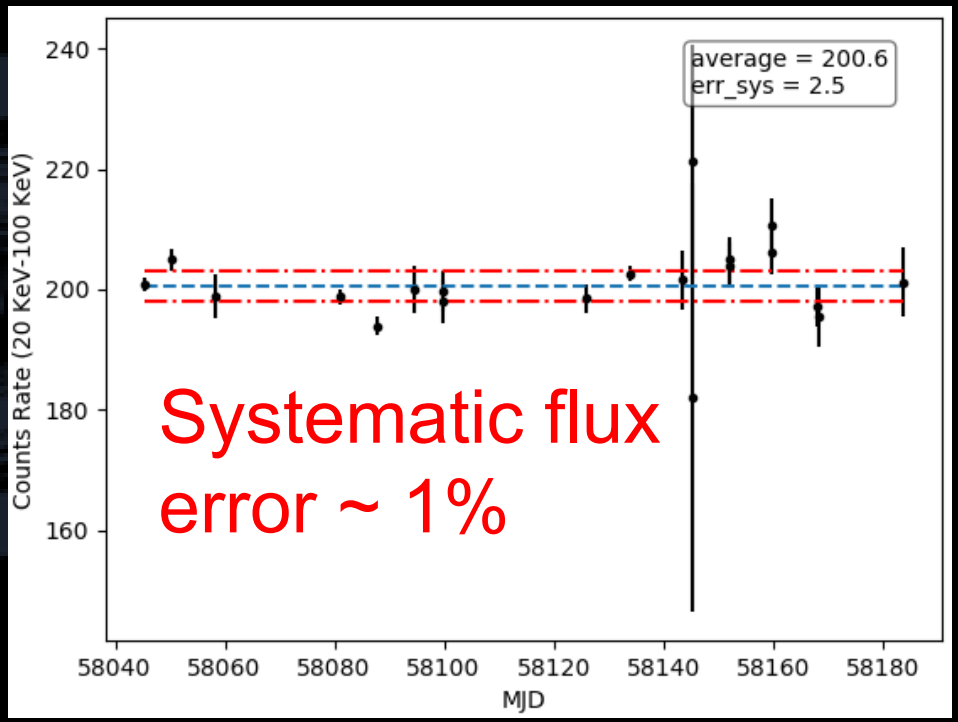


New source candidate：flux～7mCrab，～7.1σ

Long-term light curve monitoring

Monitor long-term variations of ~200 sources





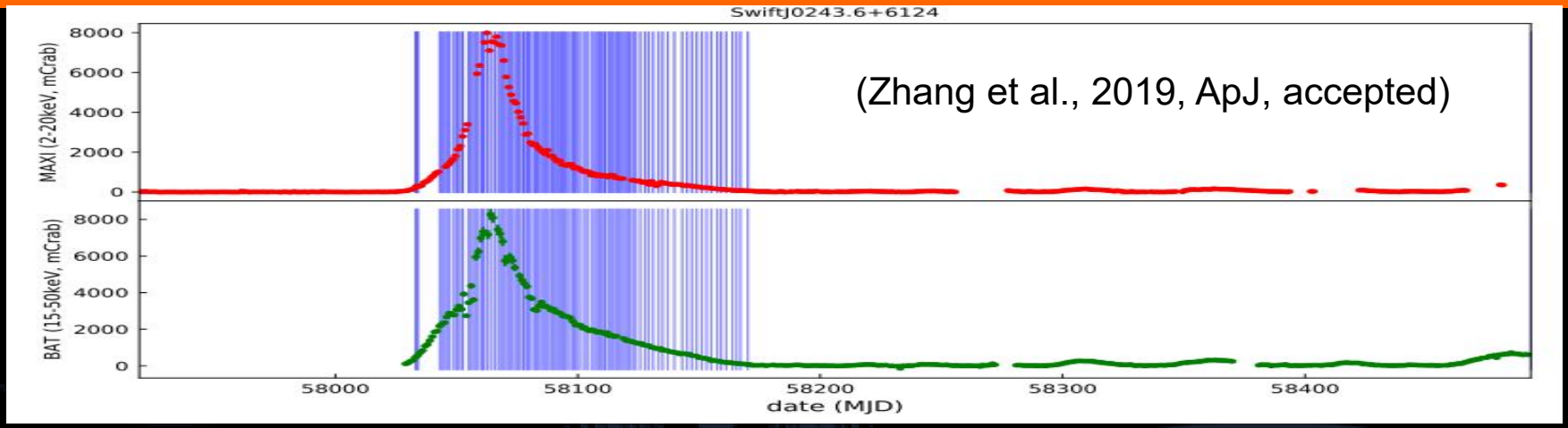
ME (7-40 keV)
Swift J0243.6+6124
Accreting pulsar

HE (20-100 keV)
Crab
Isolated pulsar

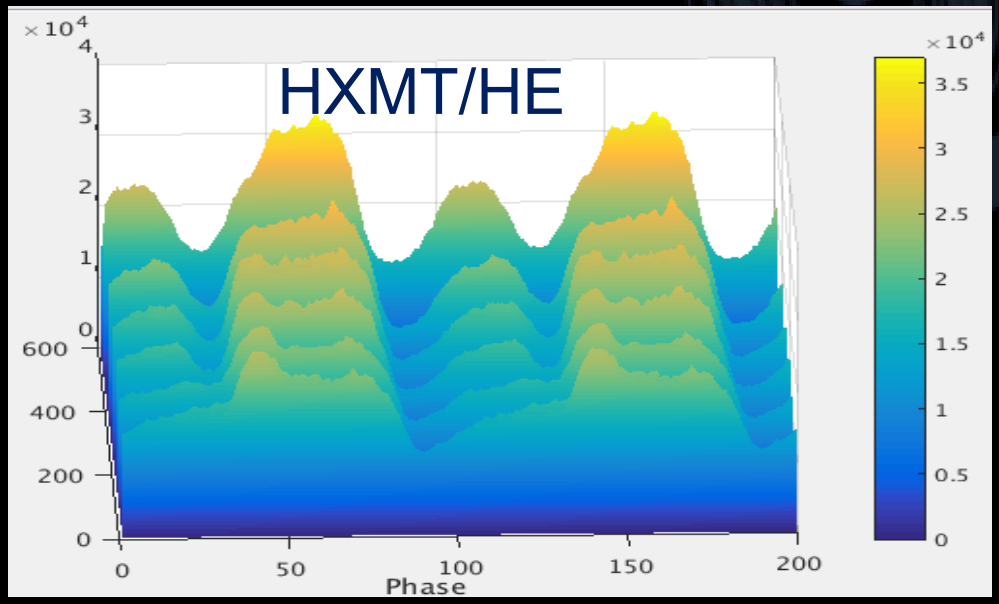
Survey in multiwavelength context

- Monitoring the flux variability in a rather broad energy band (1-250 keV), better than MAXI and BAT in energy coverage and sensitivity
- Trigger for observation of other wavelength
- Contemporary SED

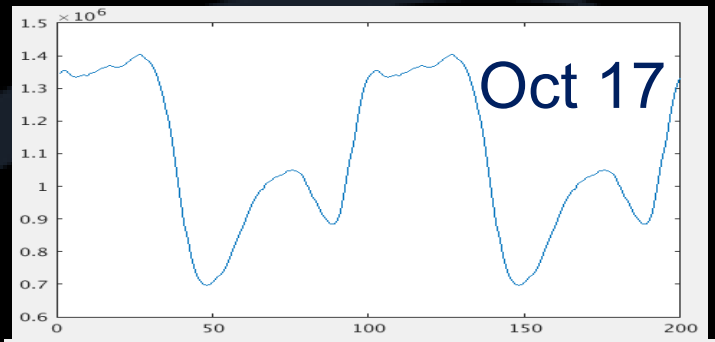
Accreting Pulsar: Swift J0243.6+6124

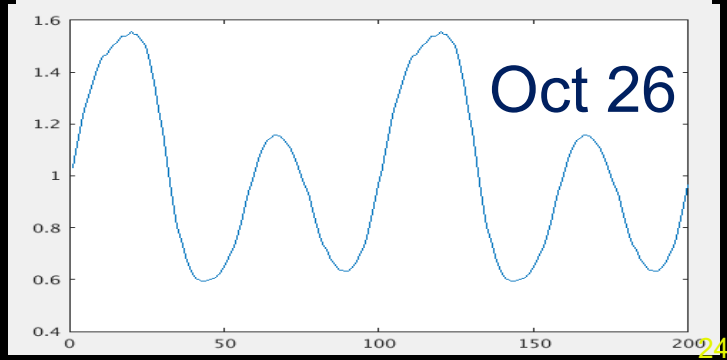


(Zhang et al., 2019, ApJ, accepted)

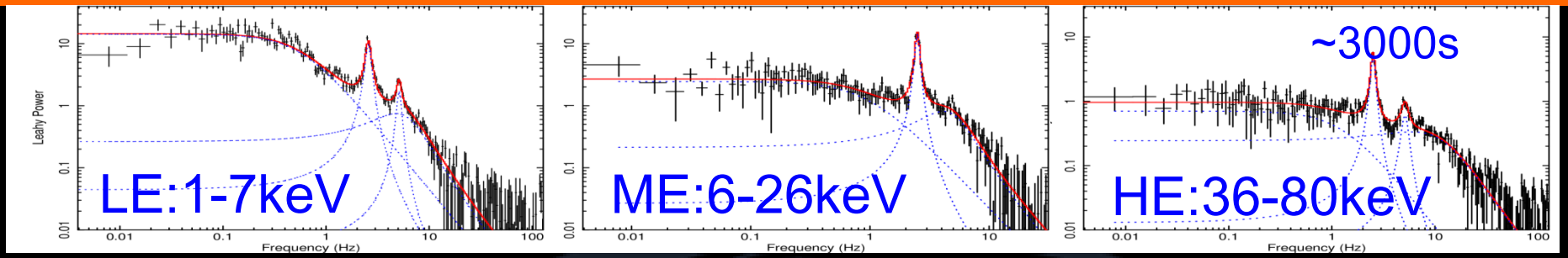


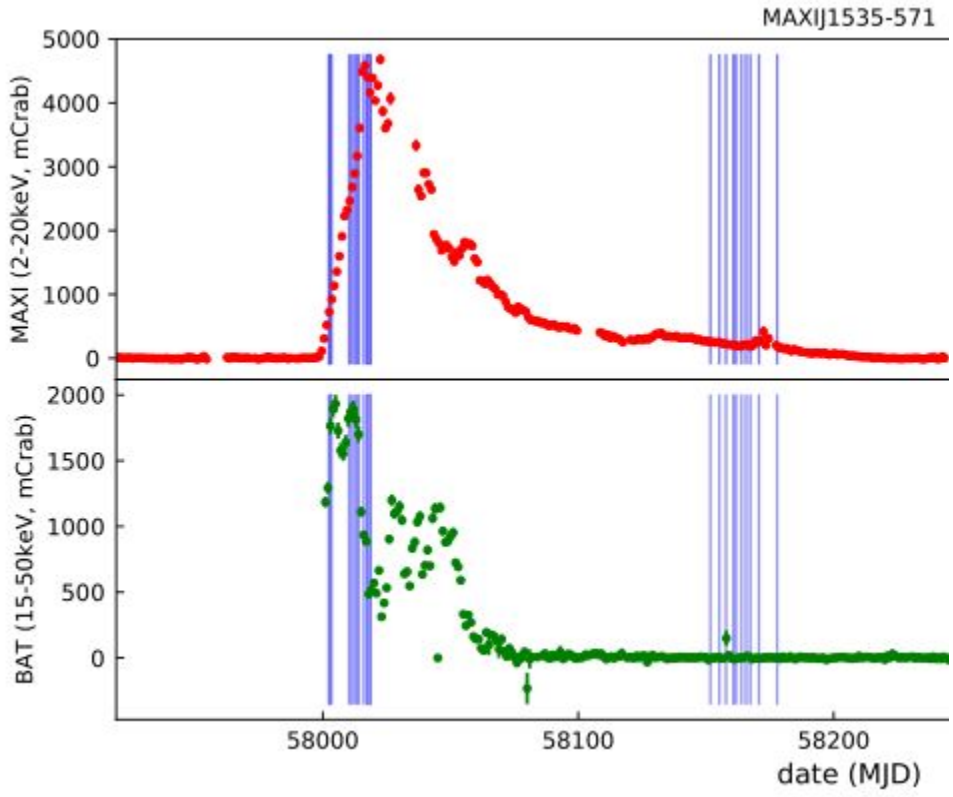
Oct 17-- Oct 23

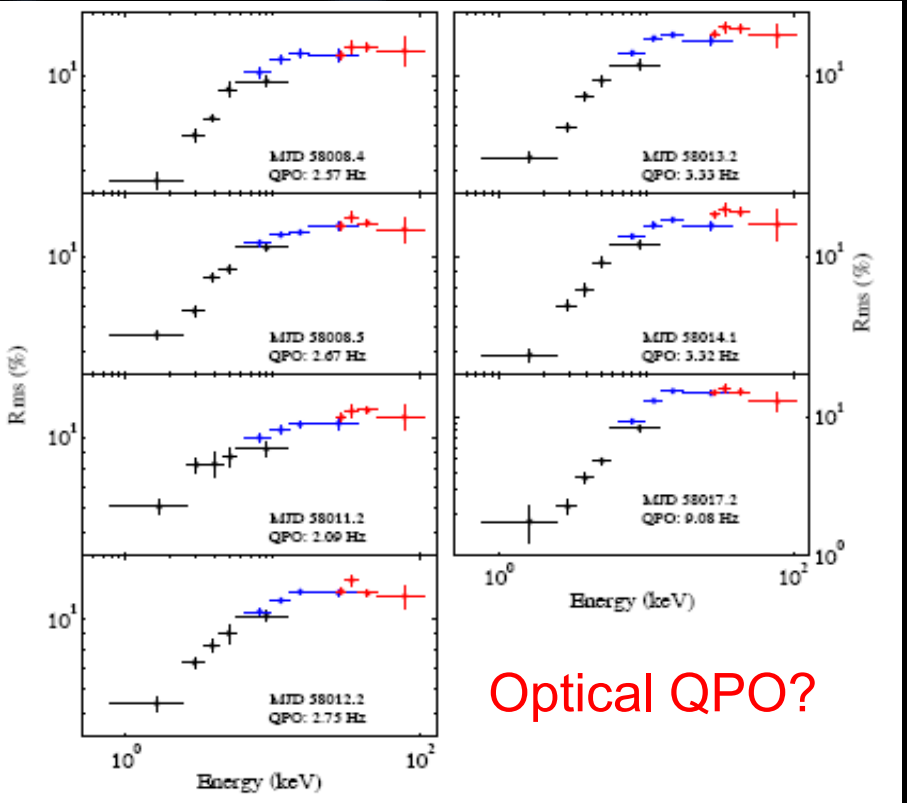




QPO observations of MAXI J1535-571







Optical QPO?

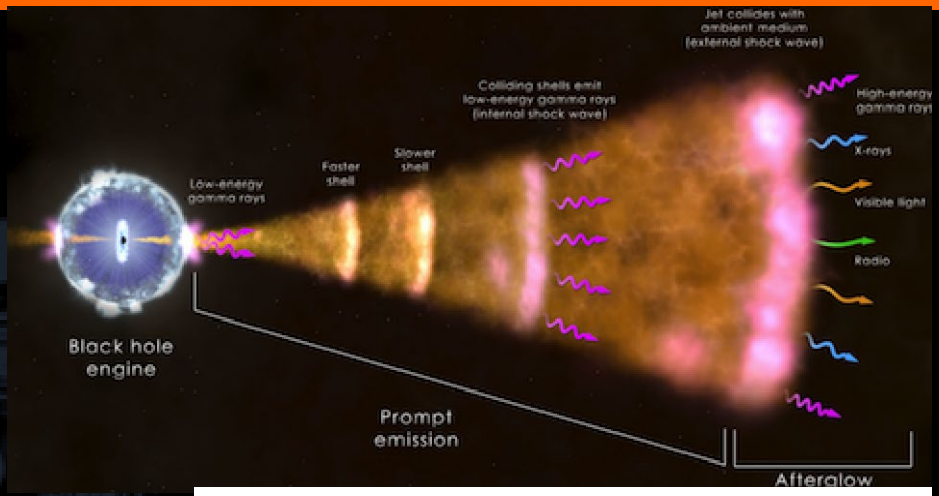
(Huang et al., 2018 ApJ)

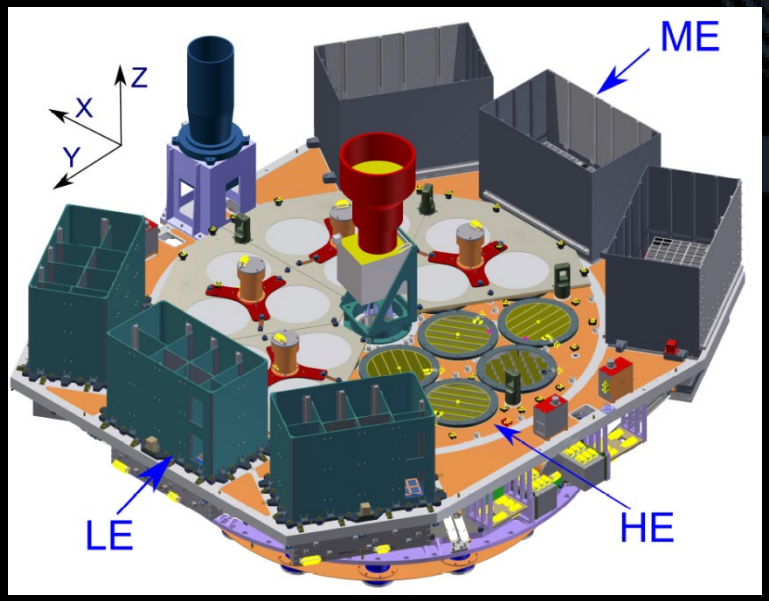
Pointed observation in multiwavelength context

- High cadence and high statistics observations in broad energy band
- Detailed information in energy and time domain
- Time lag between different energy band
- Flux correlation between different energy band
- Radio jet? Optical QPO? Doppler shifted line from companion star? Absorption line from disk wind?
- Synergy with FAST? QPO in radio?

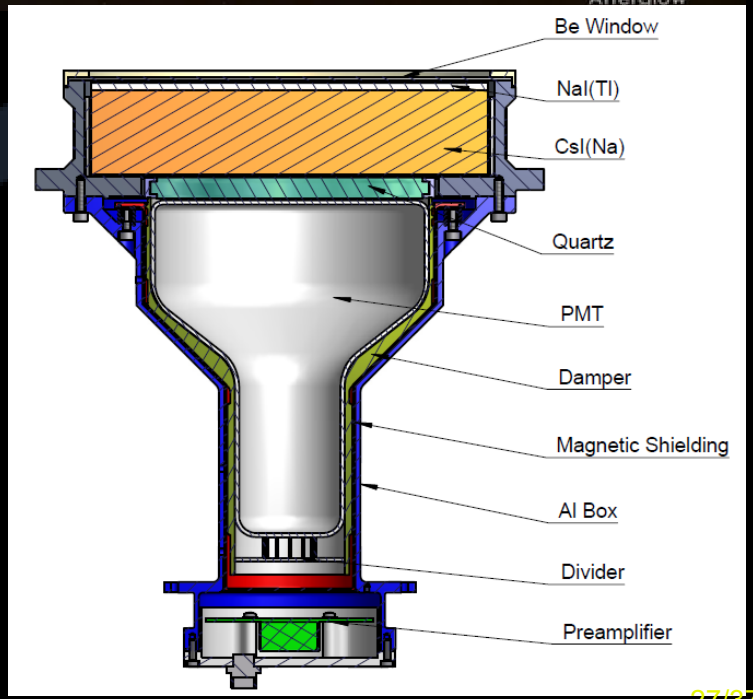
How to observe GRB (GW EM)?

- ✓Original design
  - ✓afterglow emission
  - ✓LE (0.5-10 keV), scanning
- ✓Extended capability
  - ✓prompt emission
  - ✓CsI detector of HE



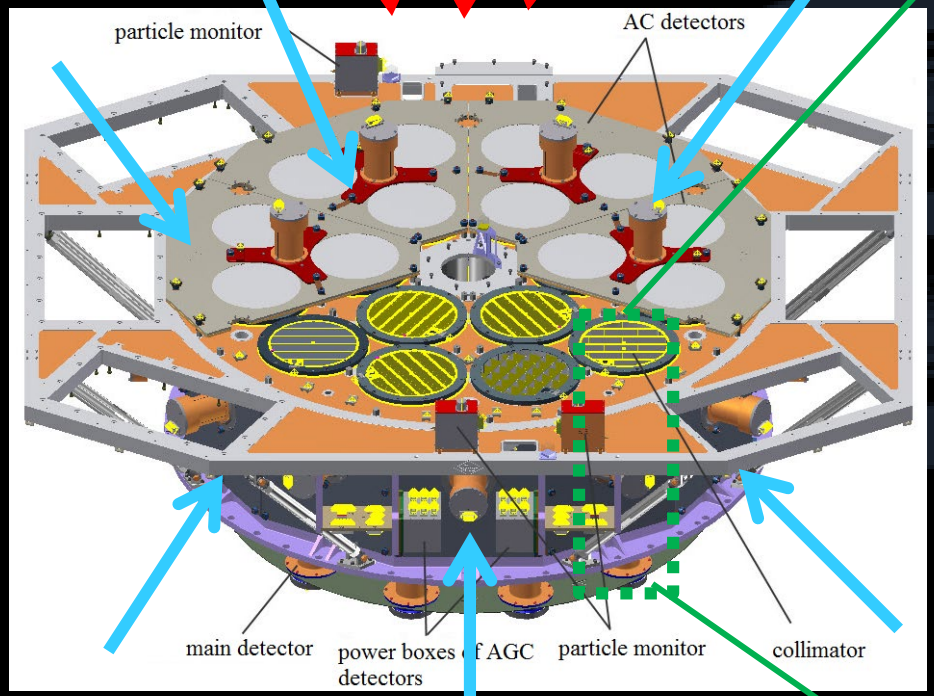


HE
NaI/CsI

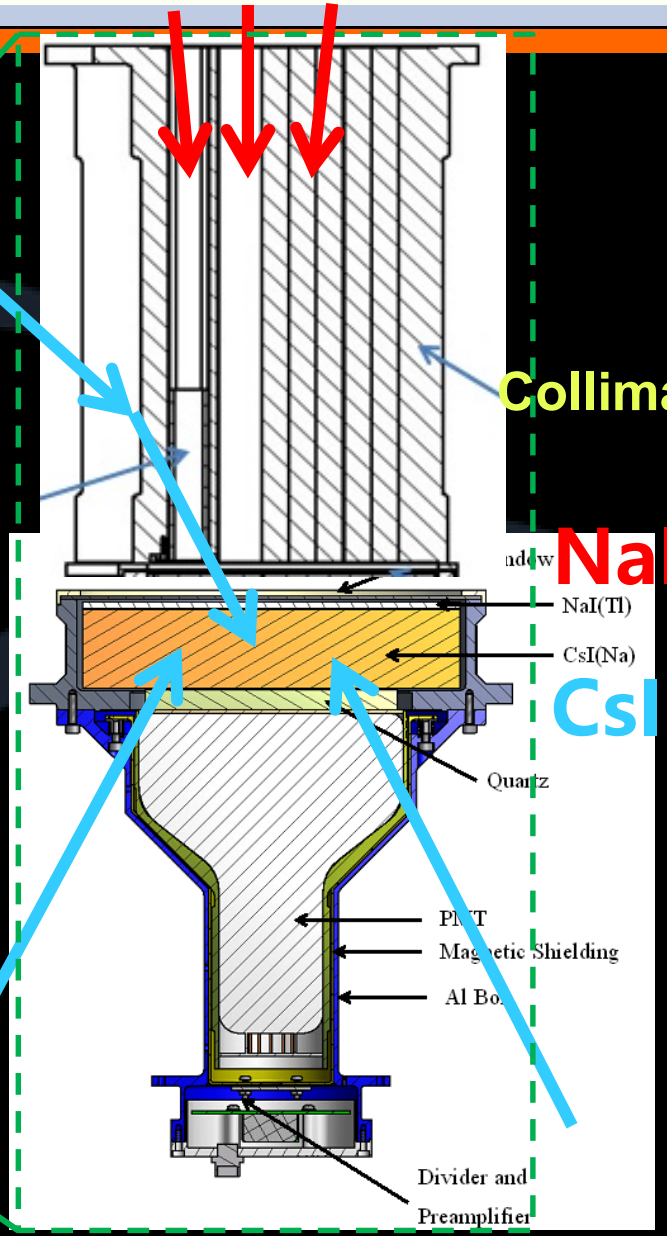


Regular observation vs. GRB observation

X/gamma photons within FOV

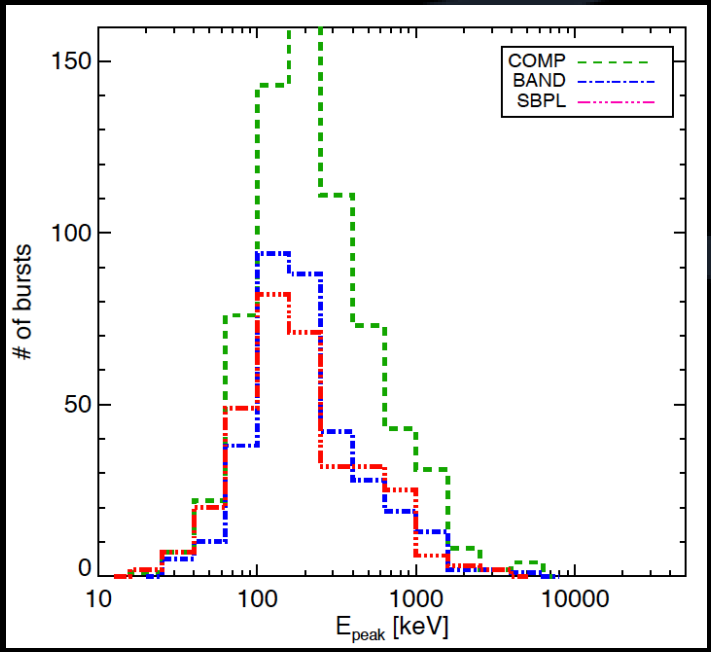


Gamma-rays
(> ~200 keV)



Dedicated working mode for GRB

Working Mode	NaI energy band (keV)	CsI energy band (keV)	Detector Setting
Regular mode	20-250	40-600	Normal HV
GRB mode	100-1250	200-3000	Lower the PMT HV, turn off the AGC

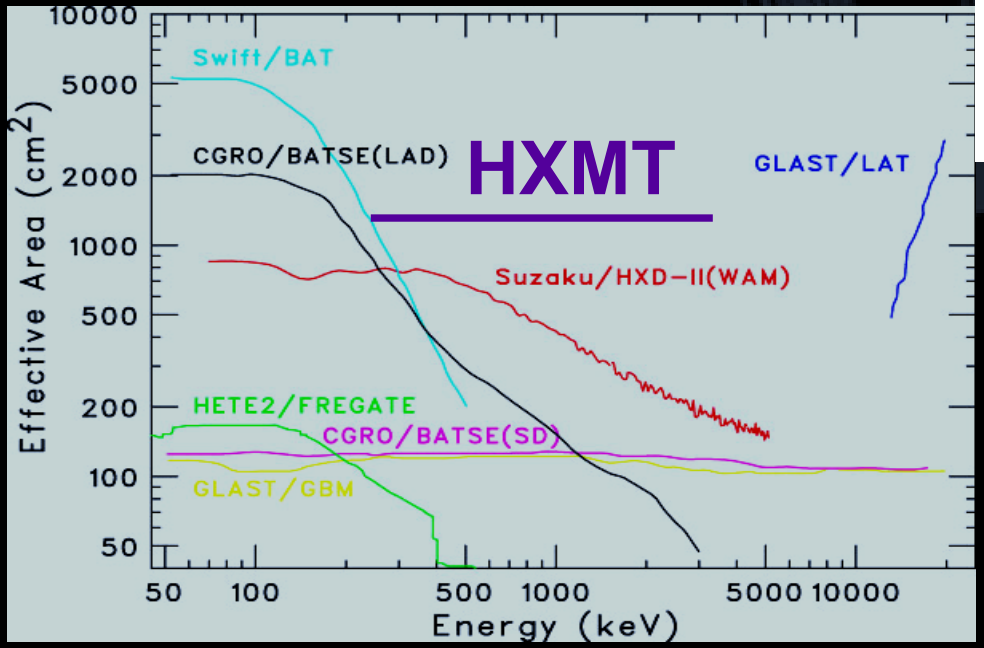


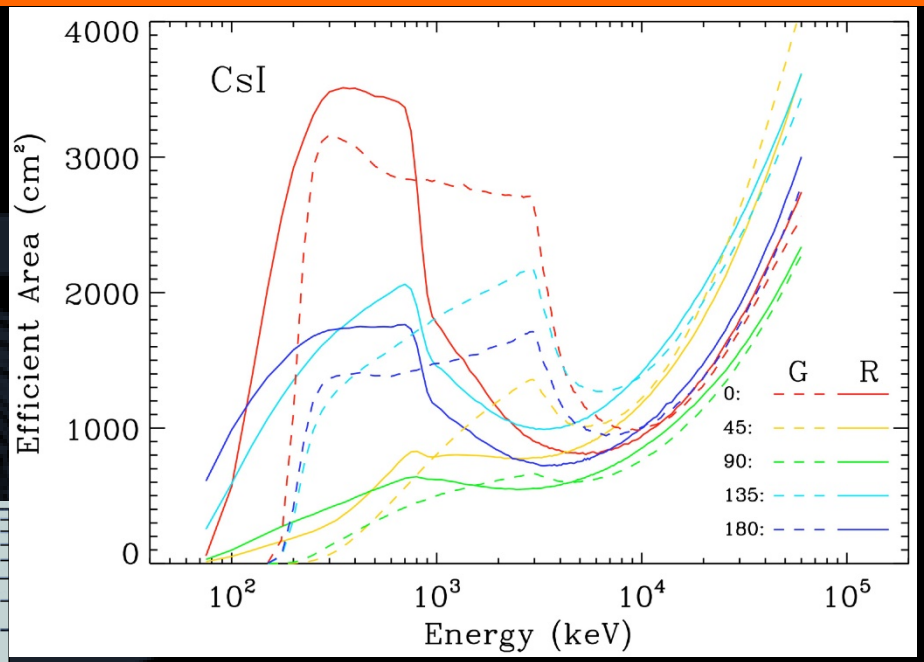
GRB Epeak measured by Fermi/GBM
（Gruber+, ApJS, 2014）

- **GRB mode better energy range:**
  - According to the simulation, det. efficiency is good for >200 keV
  - GRB Epeak distribution
- **GRB mode: ~30% of obs. time**
  - When the targeted source is occulted by the Earth in pointed observation
  - When HE regular mode is not very useful in an observation

Effective Area for GRBs

- Can detect GRBs in **both** regular & GRB modes (lower HV for PMT)
- GRB monitoring FOV: all sky un-occulted by the Earth

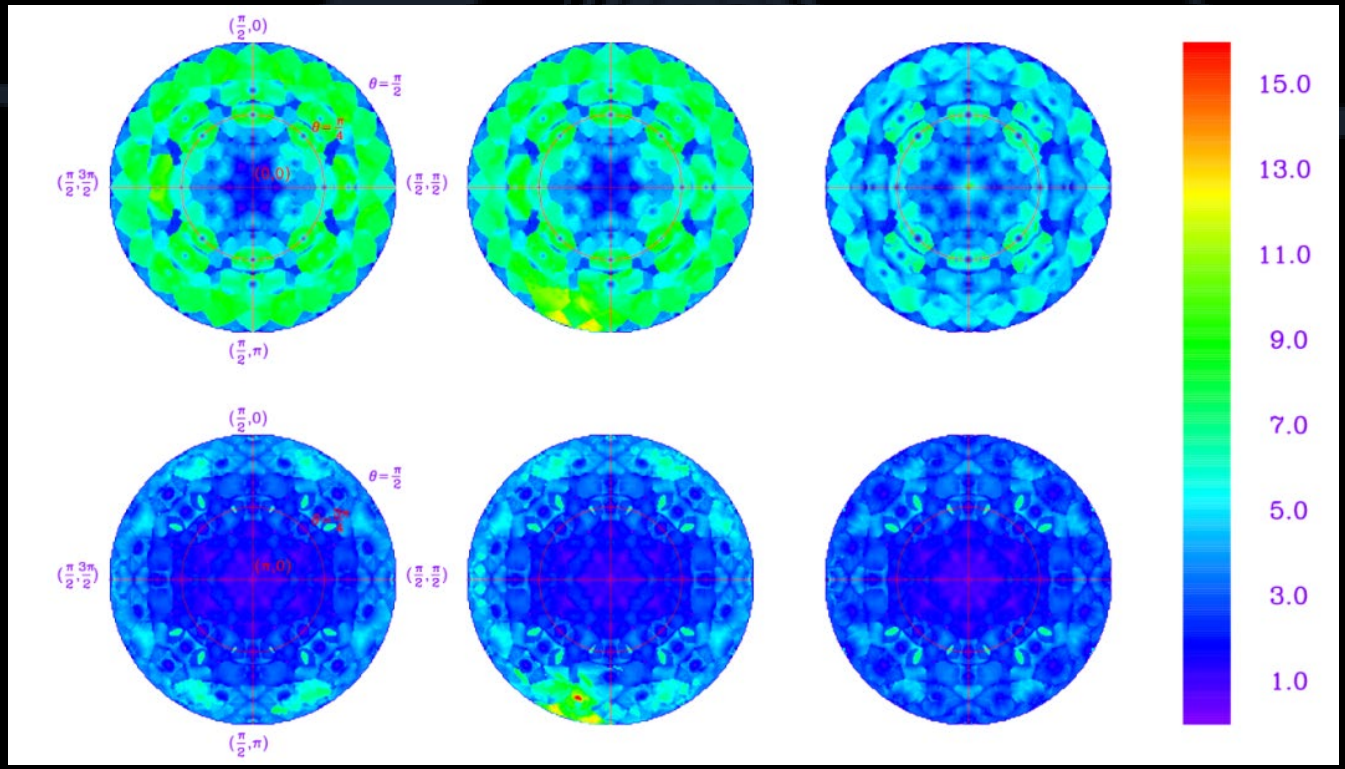




- 500~3000 cm^2 ~ MeV range with single photon counting and energy measurement, ~largest ~ MeV GRB monitors ever flown

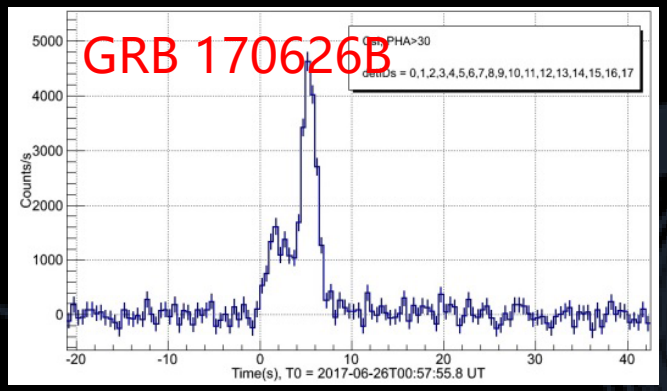
GRB & GW EM: Location & Spectroscopy

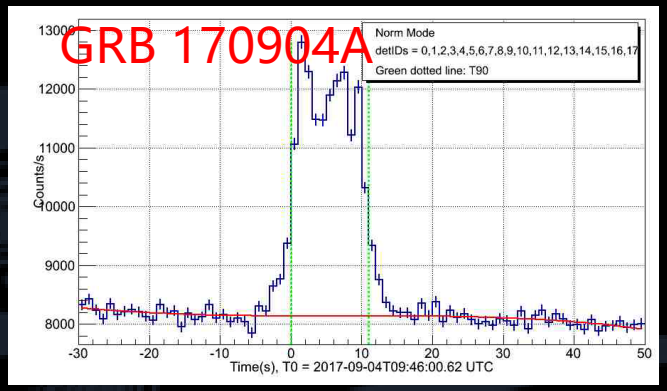
- **Wide FOV (~60% all-sky) and large eff. area (1000 cm^2) in μs**
- Temporal analysis with high statistics
- Location accuracy: ~5 deg
- Spectral analysis (Epeak)



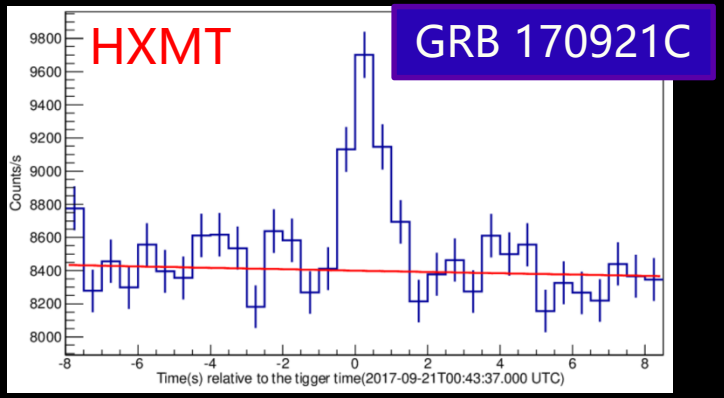
GRB Advantages

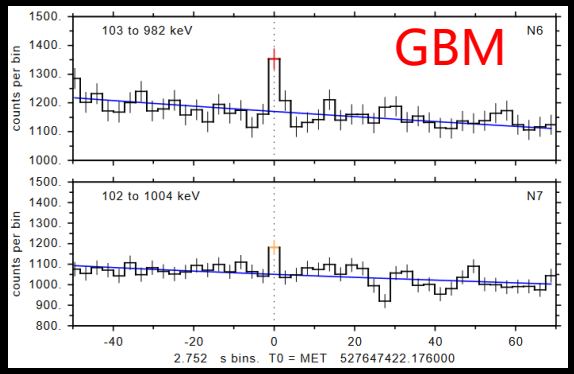
- ✓Large area: abundant photons → timing

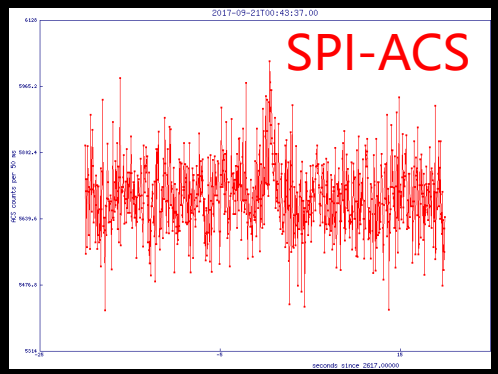




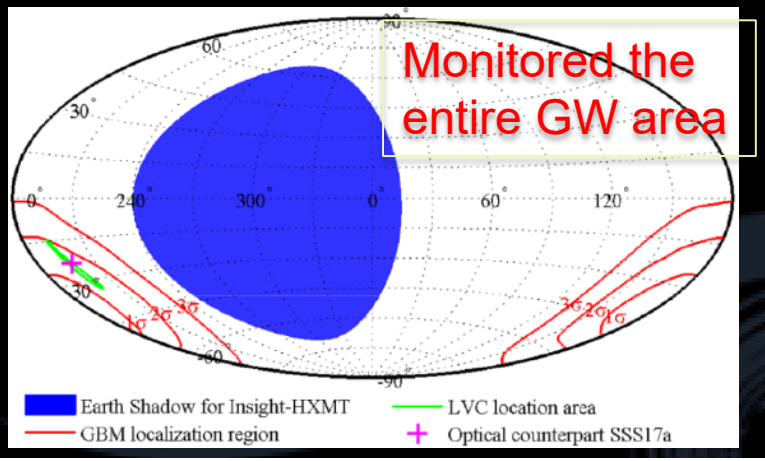
- ✓Sensitive @MeV: short/hard GRBs
  - ✓Sig: HXMT=12，GBM=8，SPI-ACS=4 (no spectrum)

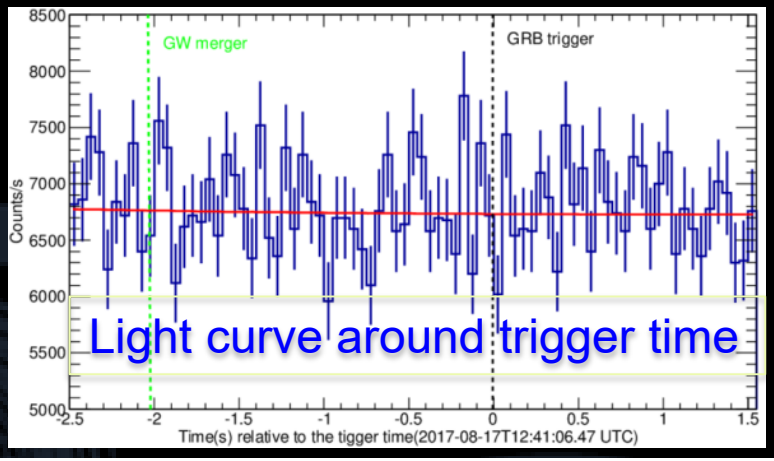


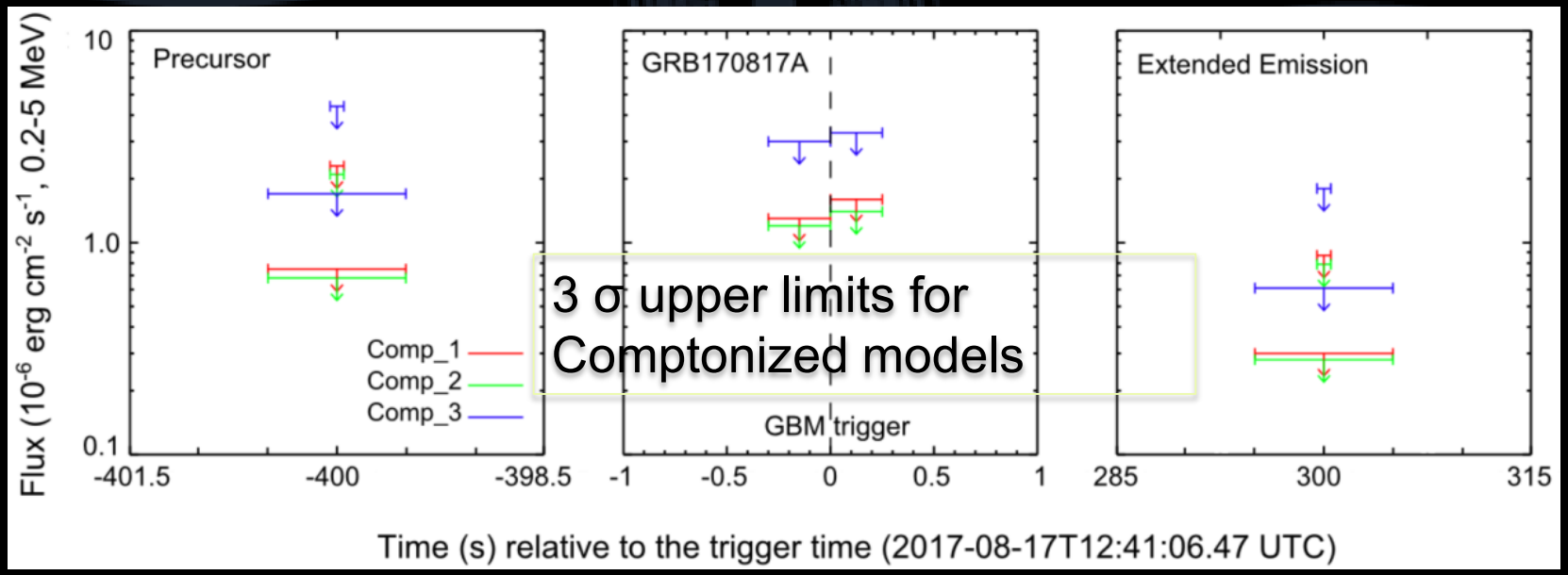




Insight-HXMT observation to GW-EM

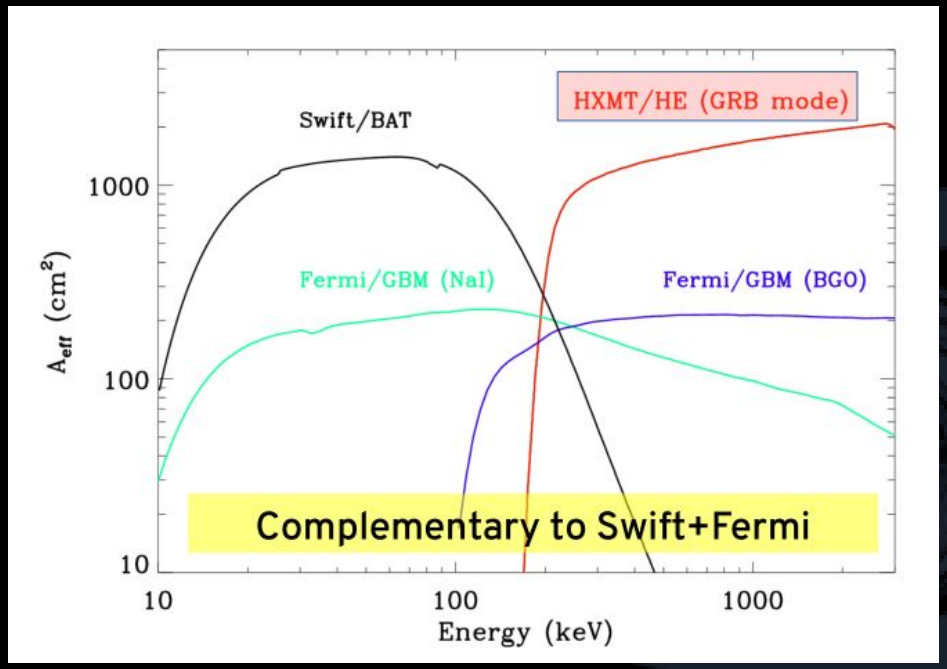


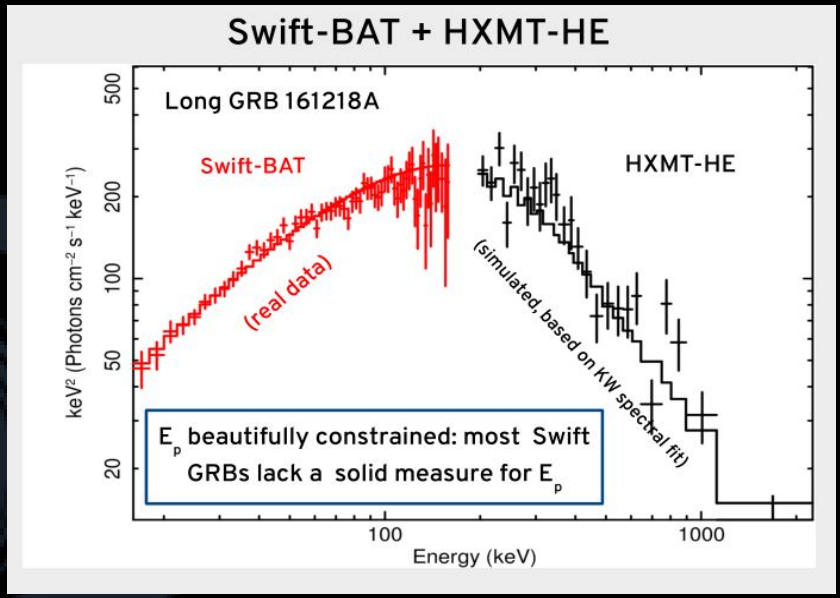


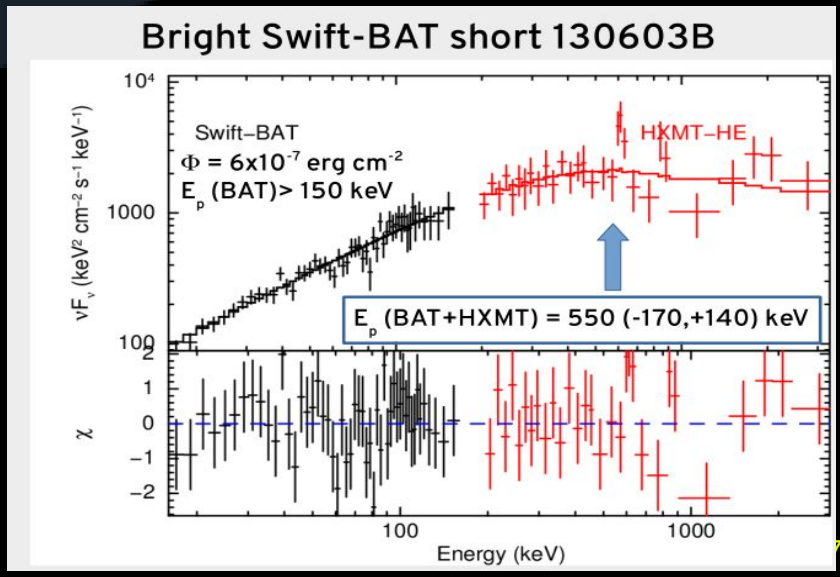


T. P. Li, et al, Sci. China-Phys. Mech. Astron. 61(3), 031011 (2018)

Prospect of GRB observations with joint missions







- ✓ Robust measurement of Epeak;
- ✓ sGRB coupled with GW.

(from Cristiano Guidorzi)

GRB observation in multiwavelength context

Almost all sky coverage at soft gamma-rays, with the best sensitivity

GRB?
GW counterpart?
TGF?
FRB?
…..

Coordinated observations

- ✓11 sources: more than 50 observations
- ✓telescopes:
  - ✓X-ray: INTEGRAL, Swift, NuSTAR, XMM-Newton, NICER, Chandra, Astrosat
  - ✓radio: FAST, radio telescope in Xinjiang, Kashima radio telescope (Japan)、Medicina radio observations (Italy), VLBI
  - ✓optical: VLT, Lijiang, Xinglong
- ✓To improve calibration
  - ✓E-C relation: Her X-1 (INTEGRAL, NuSTAR)
  - ✓response: Crab

Summary

- ✓ *Insight*-HXMT is China's 1st X-ray astronomy satellite.
  - ✓ 1-15, 5-30, 20-250 keV and 200-5000 keV (all-sky monitor mode)
- ✓ *Insight*-HXMT PV & calibration: June 15 to Nov. 15, 2017
- ✓ Insight-HXMT normal observations: ~ 1.5 years
  - ✓ 7 papers published/submitted
  - ✓ > 10 papers in preparations
- ✓ Collaborations welcome: three ways
  - ✓ Partner institutions that contributed to *Insight*-HXMT
  - ✓ Coordinated multi-λ observations: space & ground
  - ✓ Apply and join our teams

http://www.hxmt.org/ for all information.