Current and Near-Future (<2030) Space High Energy Astronomy Missions of China

--eXTP as a showcase

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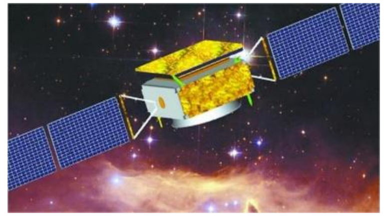
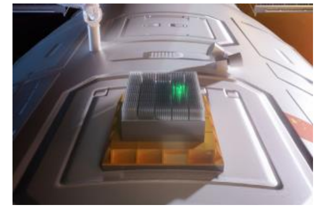
China’s Space High Energy Astronomy Missions

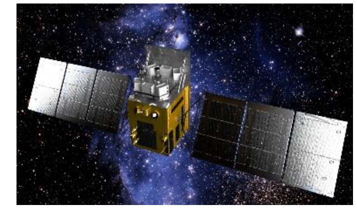
- **DAMPE (2015)**
- ***POLAR (2016)***
- ***Insight*-HXMT (2017)**
- ***GECAM (2020)***
- **SVOM (2024)**
- **EP (2023)**
- **POLAR-2 (2025)**
- ***HERD (2027?)***
- ***eXTP (20279)***



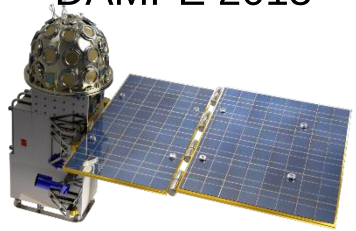
DAMPE 2015



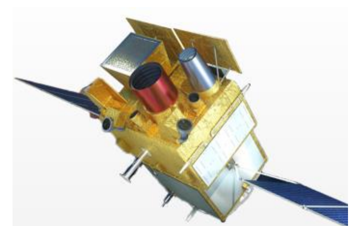
POLAR 2016



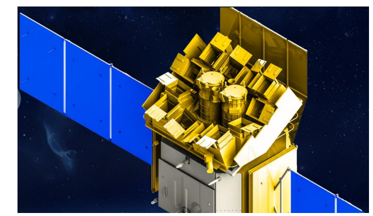
HXMT 2017



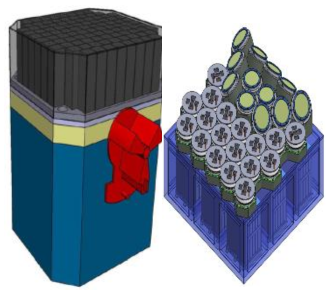
GECAM 2020



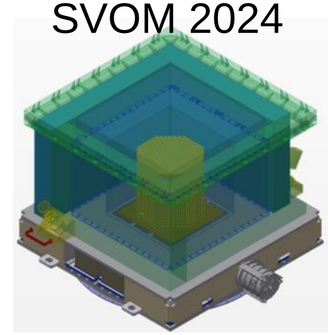
SVOM 2024



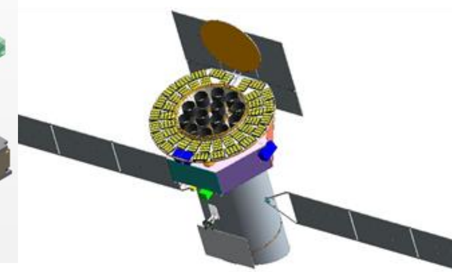
EP 2023



POLAR-2 2025



HERD 2027?



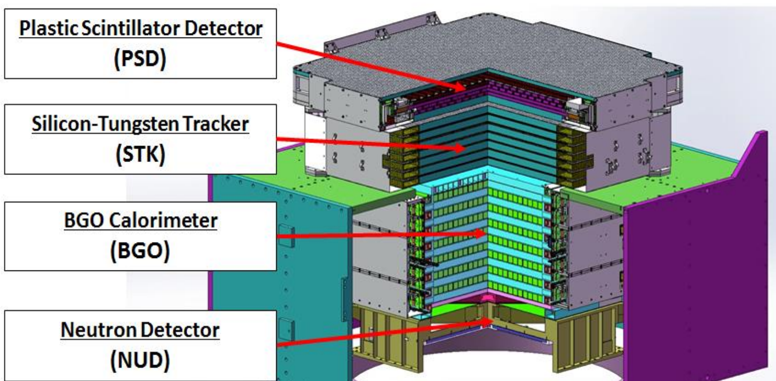
eXTP 2029?

*Missions led by our teams in PAD/IHEP

Proposed missions ≥ 2030 not included, e.g., VLAST, CATCH

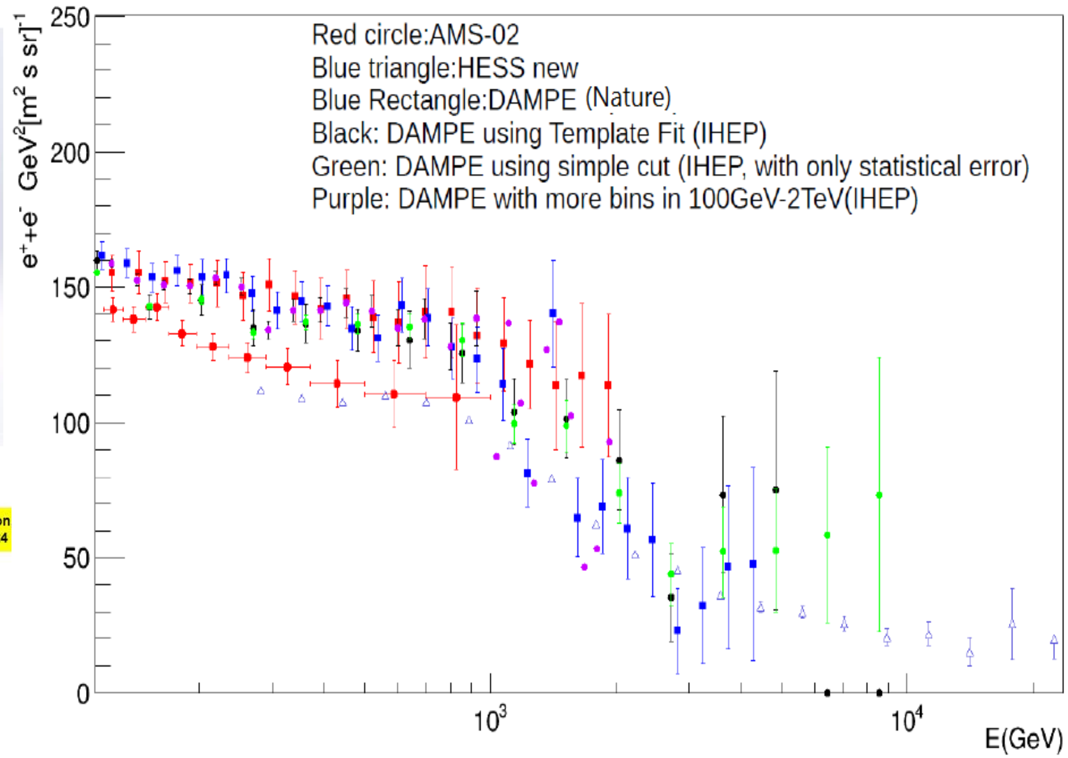
DAMPE (Dark Matter Particle Explorer)

- China's first astronomical satellite, Dec. 17th, 2015.
- Made the most precise measurement of the high energy spectrum of cosmic electrons
- Possible evidence for dark matter particle, but debated



- Charge measurement (dE/dx in PSD, STK and BGO)
- Pair production and precise tracking (STK and BGO)
- Precise energy measurement (BGO bars)
- Hadron rejection (BGO and neutron detector)

J. Chang et al. DAMPE Collaboration Astroparticle Physics 95 (2017) 6–24

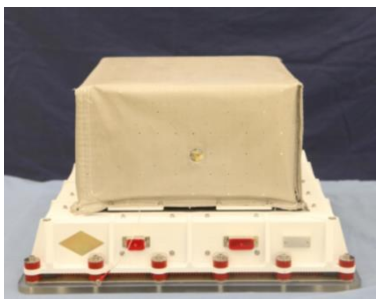


DAMPE 100 GeV-10 TeV电子正电子能谱结果

PI: Prof. Jin Chang, Purple Mountain Observatory, CAS

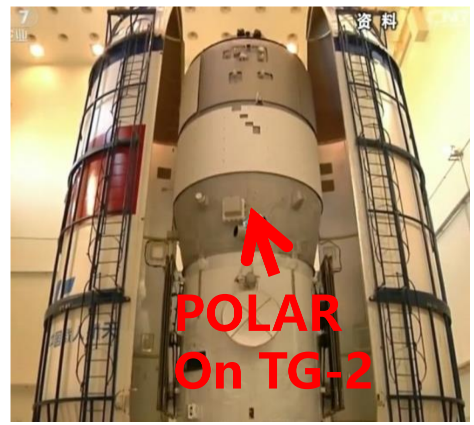
POLAR: GRB polarimeter

- China-Europe collaboration space program, onboard China's Space Lab., **Sept. 15, 2016**
- Most sensitive Gamma-Ray Burst polarimeter!
- Discovered 55 GRBs & obtained the largest sample of GRB polarization with high precision!



Detector

Electronics



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PAUL SCHERRER INSTITUT
PSI

ANNECY lapp

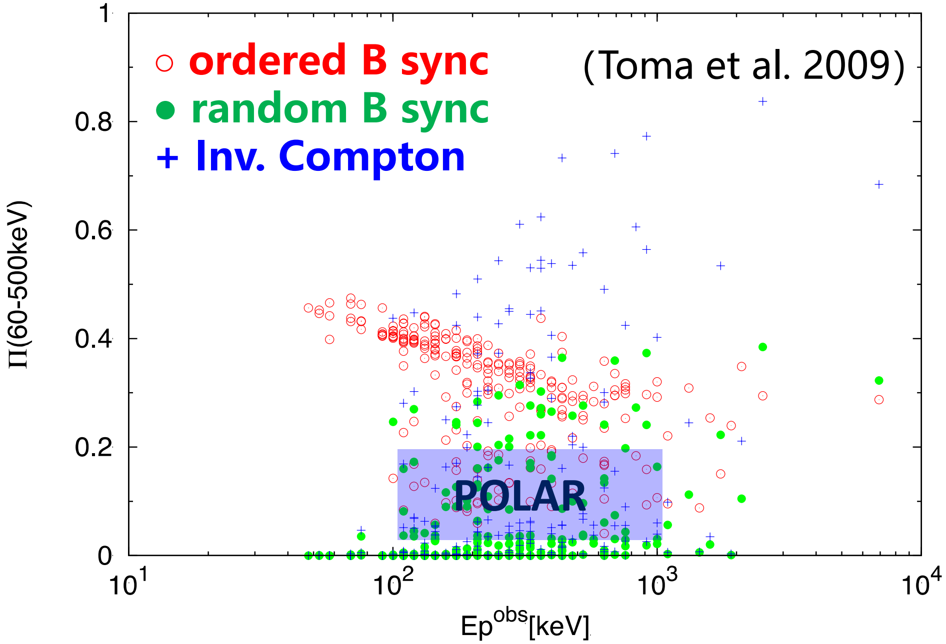
PIs: Shuang-Nan Zhang (IHEP), Martin Pohl & Xin Wu (UniGe)

POLAR's main results: contradicting most models

Table 1: Summary of the five GRBs selected (*in units of erg/cm^2 in 10-1000 keV)

GRB	T90 (s)	Fluence*	PD	Prob(PD<2%)	PD_{up}(99%)	PA(deg.)	PA Change
161218A	6.76	1.25×10^{-5}	9%	9%	45%	40	No
170101A	2.82	1.27×10^{-5}	8%	13%	31%	164	No
170127C	0.21	7.4×10^{-6}	11%	5.8%	67%	38	Unknown
170206A	1.2	1.34×10^{-5}	10%	12%	31%	106	No
170114A	8.0	1.93×10^{-5}	4%	14%	28%	164	Yes
170114Ap1	N/A	N/A	15%	8%	43%	122	N/A
170114Ap2	N/A	N/A	41%	0.49%	74%	17	N/A

170114A: 1st single peak GRB observed with pol. ang. evolution.



Comparison of obs. vs theory:

- **POLAR's 5 GRB pol.**
  large-scale random B
- **GRB 170114A pol.**
  Time-resolved high pol.
  Time-integrated low pol
  Pol. ang. varied significantly
  →→ Large-scale B evolved significantly with time

Zhang et al. Nature Astronomy 2019

Insight-HXMT

- The 1st X-ray satellite in China, 06/15/2017
- Features:
  - Large effective area @ > 30 keV
  - High timing resolution: single event mode
  - Wide energy bands (1-250 keV narrow FoV, 0.2-3 MeV as ASM)
- Status:
  - All instruments perform Focus on bright sources
  - Unrestricted number of ToOs
    - Response time: hours to days
    - *Ad hoc* ToO data public immediately
  - In AO3; AO4 released and open for all astronomers world wide
  - To stay in orbit for >8 years

sciencemag.org

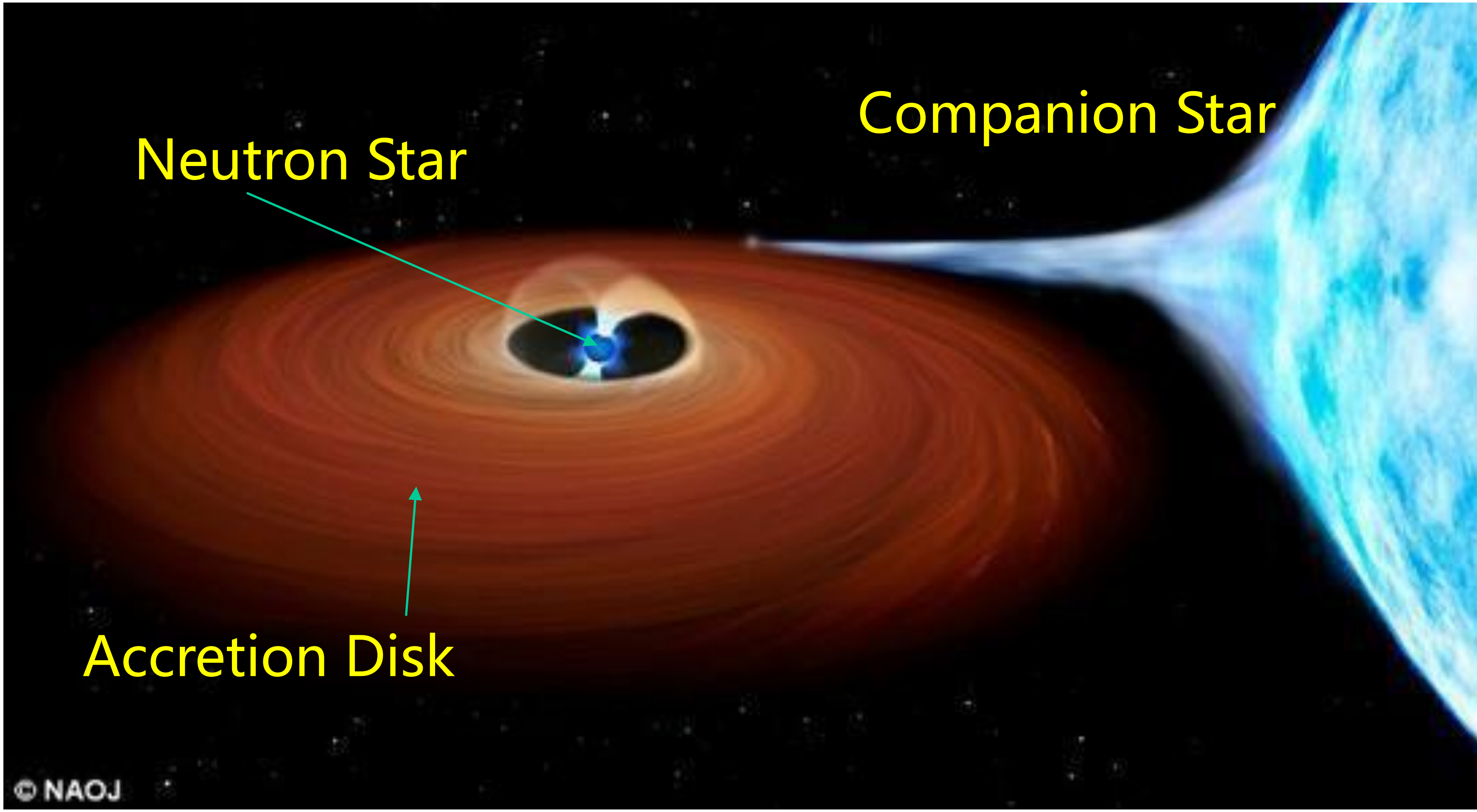
China successfully launches x-ray satellite | Science

By Dennis NormileJun. 15, 2017 , 11:00 AM

4-5 分钟

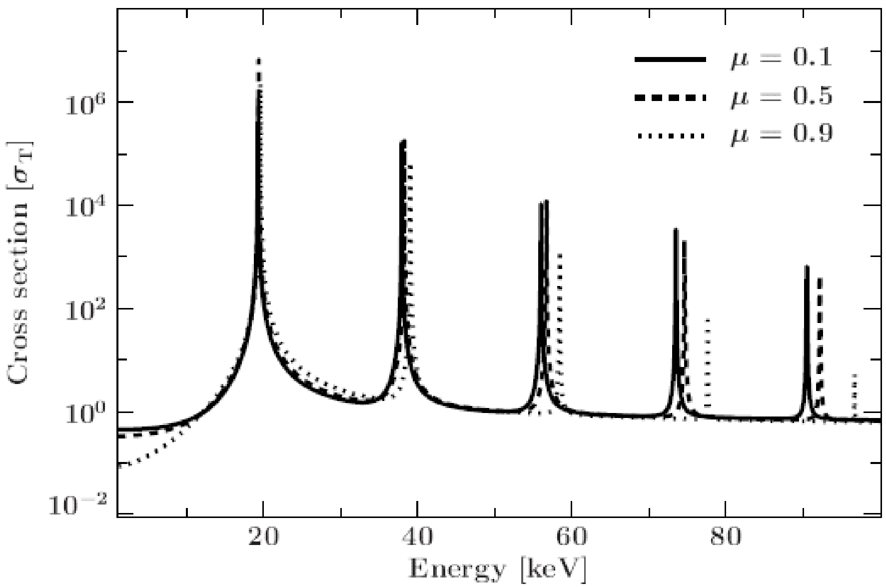
PI: Shuang-Nan Zhang (IHEP)

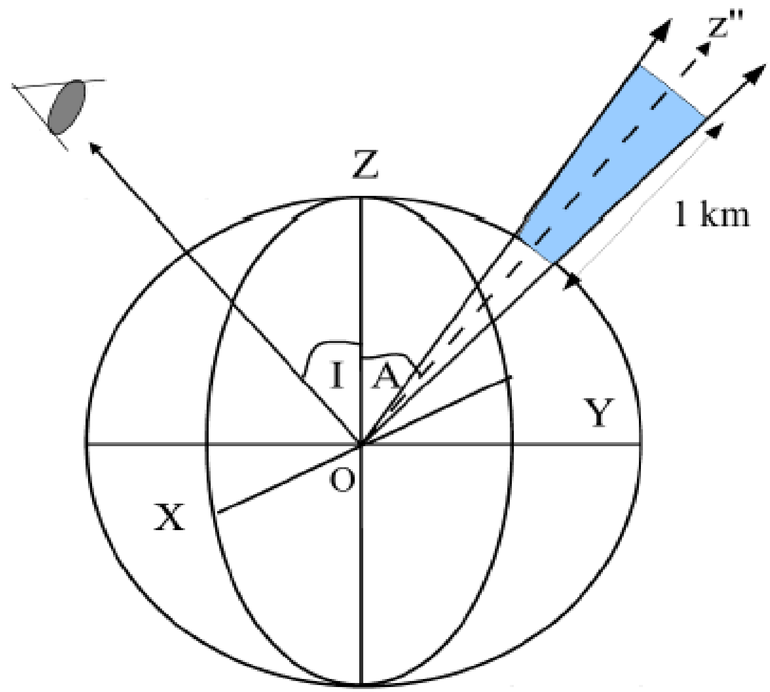
Extremely Complex Interactions in NSXBs



Extreme Magnetism near Neutron Stars

$$E_n = (m_e c^2)\frac{\sqrt{1 + 2n\frac{B}{B_{crit}}\sin^2\theta} - 1}{\sin^2\theta} \times \frac{1}{1+z}$$





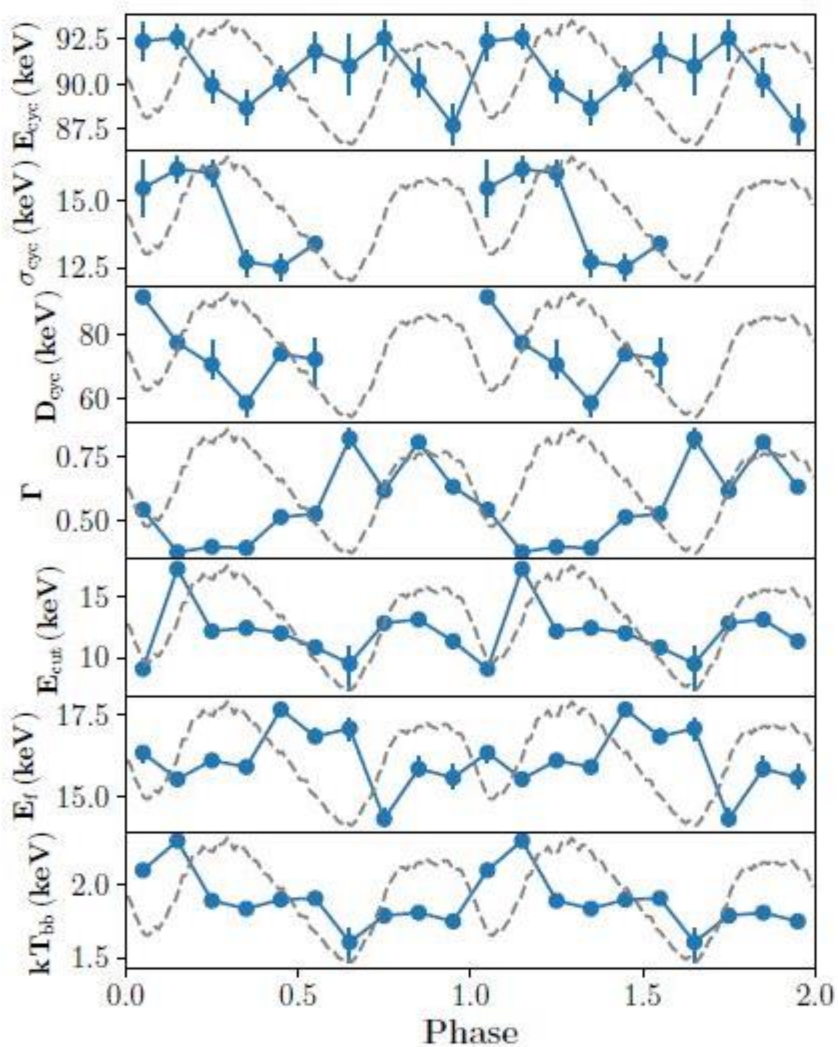
Maitra 2016

High-E Neutron star cyclotron absorption line

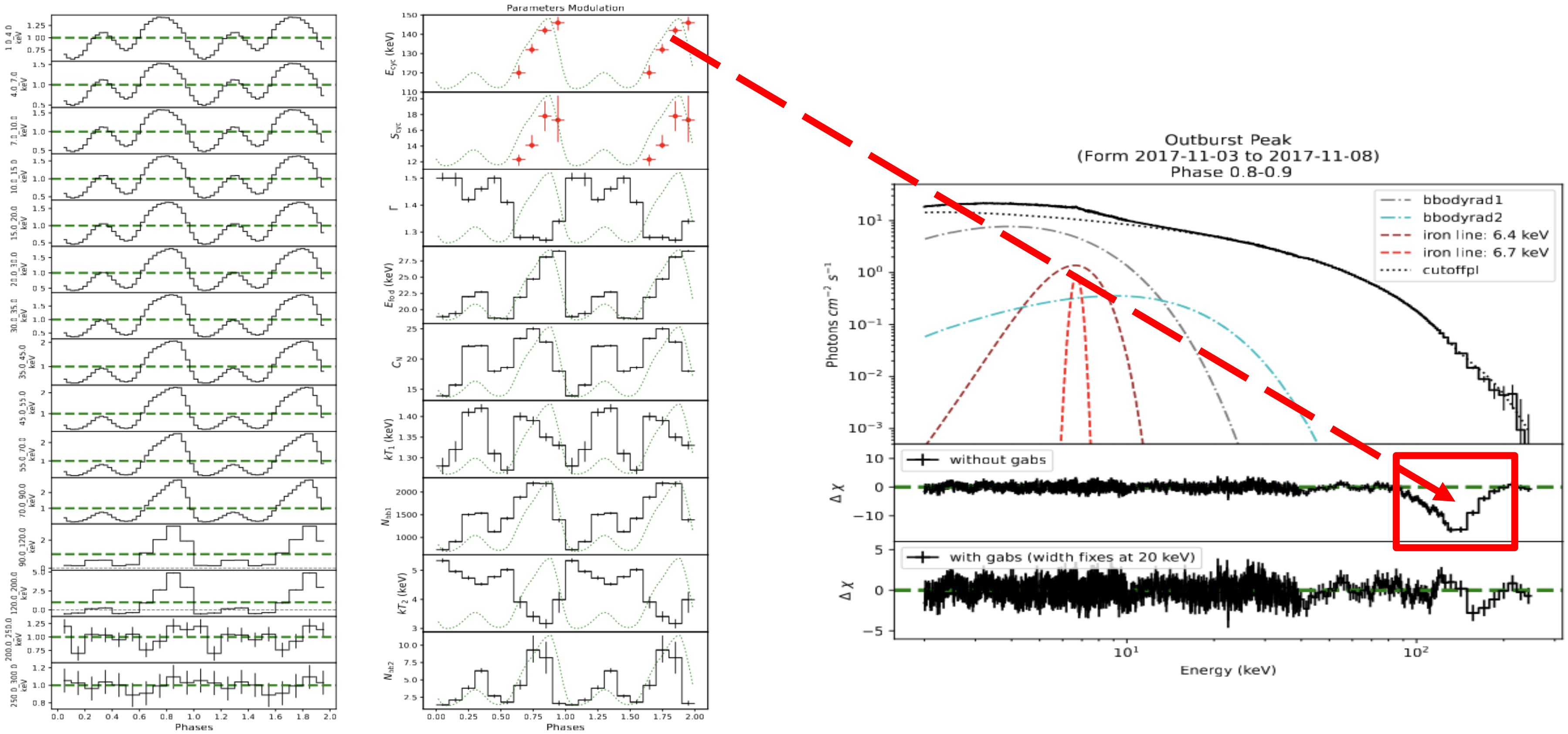
- GRO J1008-57： ~90 keV → highest *B* directly measured in the universe ~10^{13}, ~ 4σ with NuSTAR & Suzaku ~79 keV
- 4 HXMT observations ~235 ks ~ 20σ detection

Allow for phase resolved and flux dependent studies

Ge et al. 2020

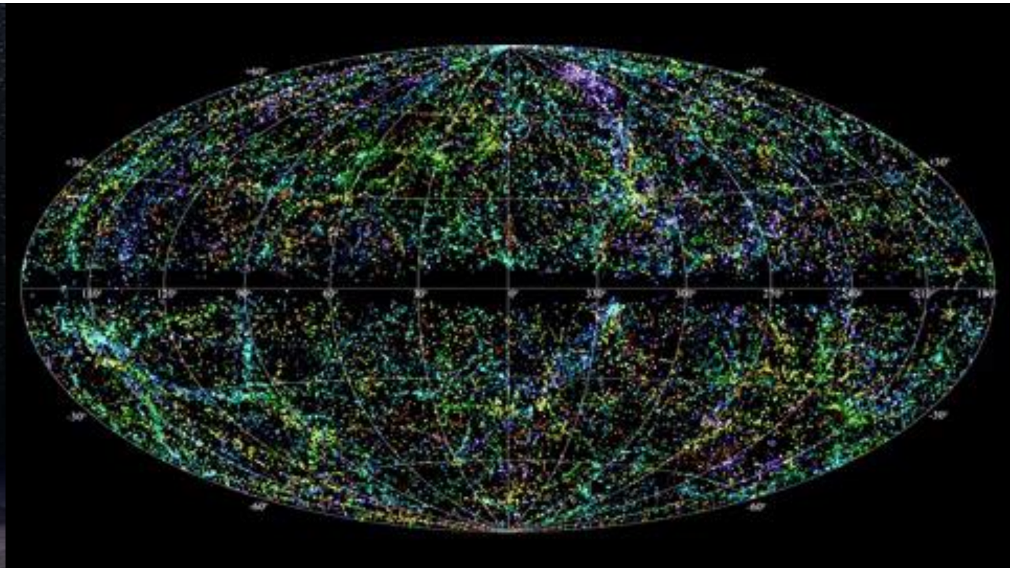


Highest-E Neutron star cyclotron absorption line



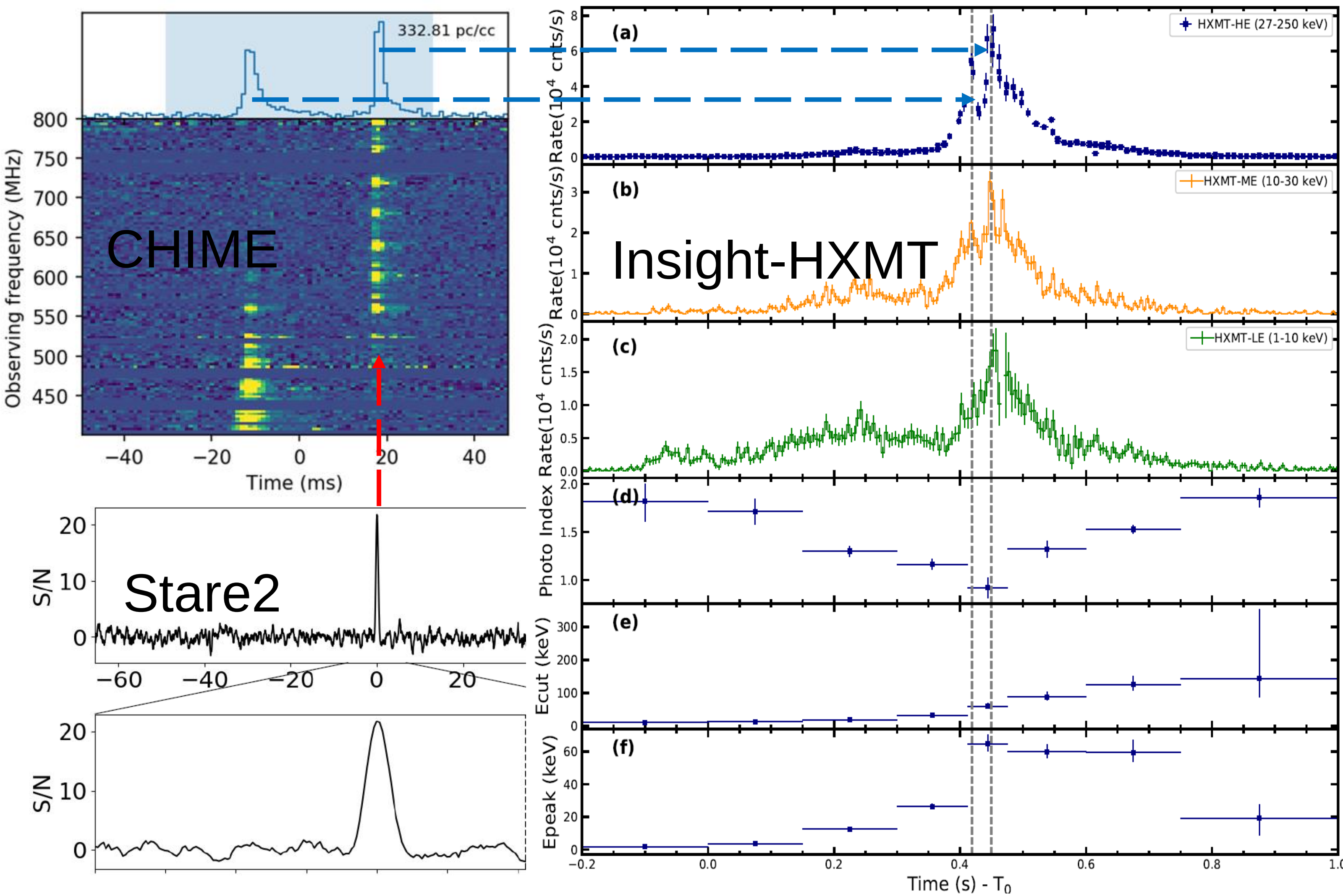
1st Galactic ultraluminous X-ray pulsar Swift 0243: 146 keV→1.6×10^{13} G >> ~10^12 G dipole B-field: evidence for multipole B-field? (Kong+2022)

Fast Radio Bursts



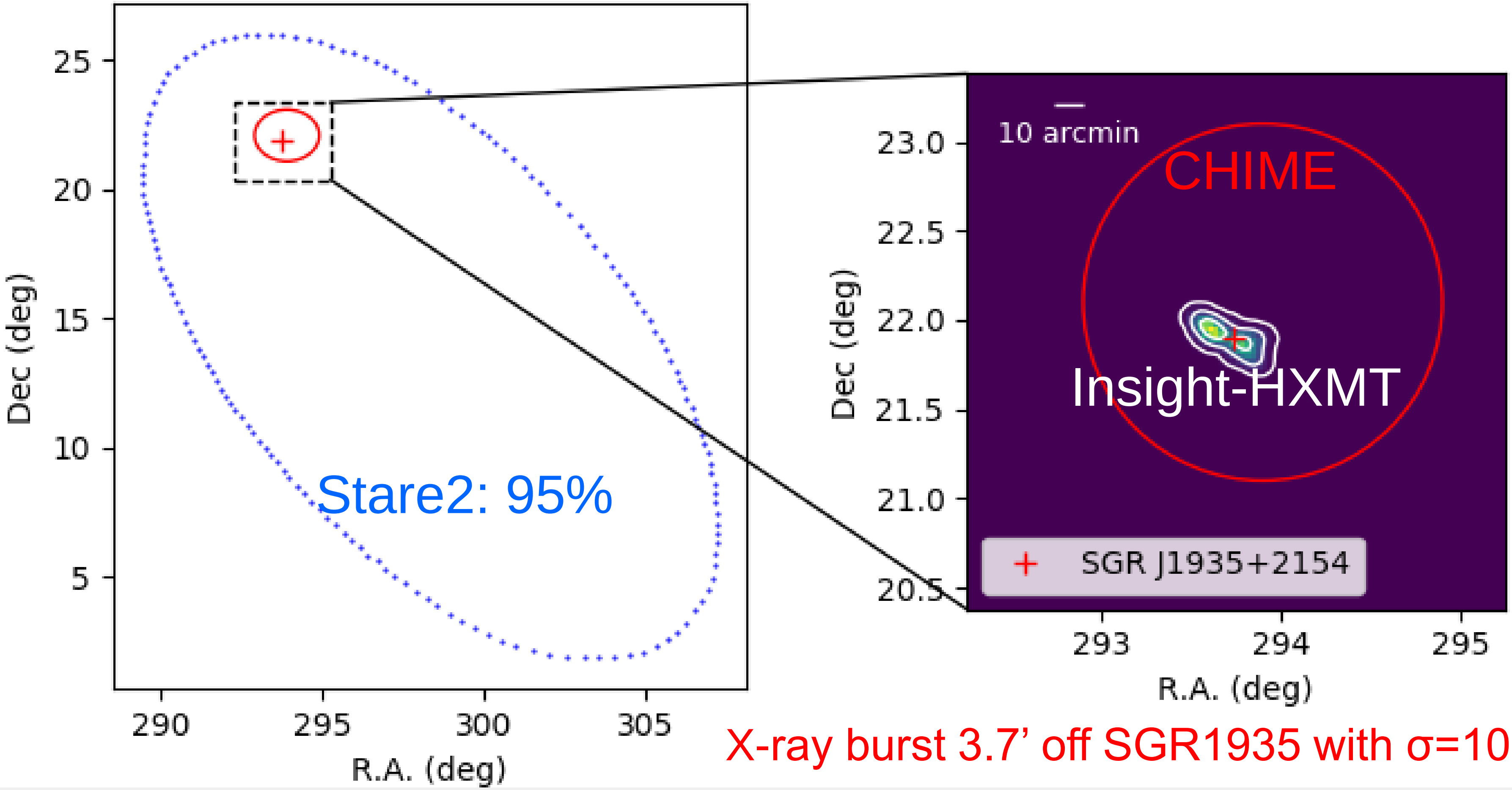
First reported in 2007 (Lorimer et al. 2007): bright millisecond radio pulses, random arrival direction and time, some repeat and even periodic, but counterpart or radiation at any other wavelengths not known, until April 28th, 2020.

Historic event on April 28th 2020



CHIME/FRB Collaboration+; Bochenek+; Li+, 2021, Nature Astronomy

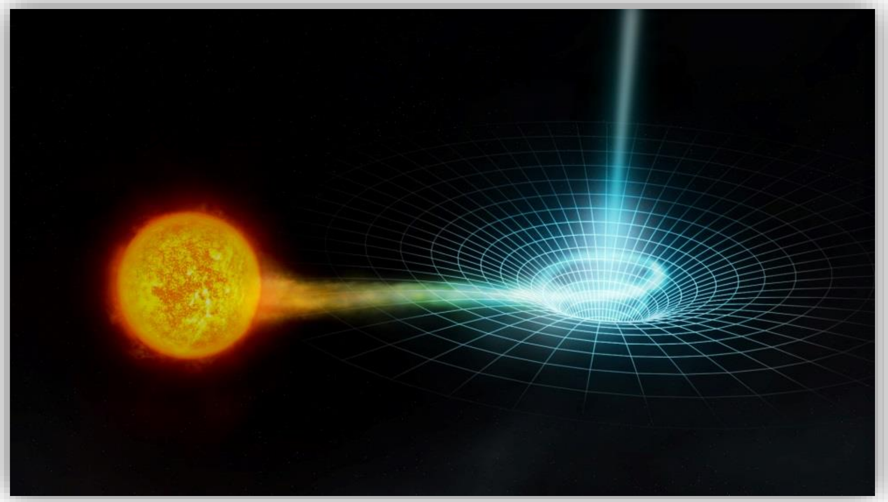
Localization of the X-ray burst

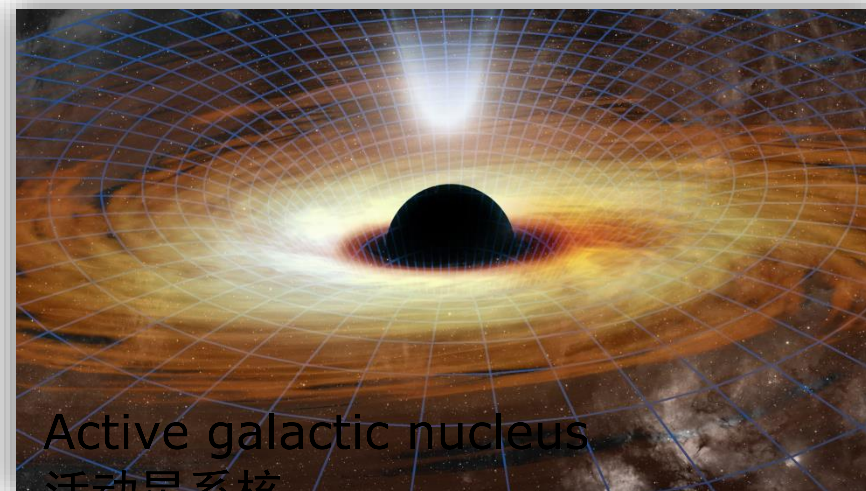


X-ray burst 3.7' off SGR1935 with σ=10"

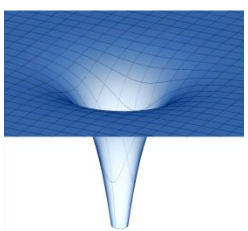
Identification of the X-ray burst with SGR1935, Li+ (Insight-HXMT team), 2021, Nature Astronomy

Extreme Gravity Near Black Holes

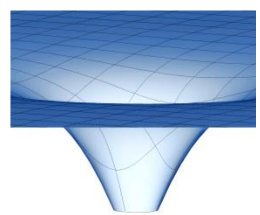




X-ray study covers wide mass range in uniform setting



Stellar mass black hole
(or neutron star)
Strongly curved spacetime.
(10^{16} times Solar)



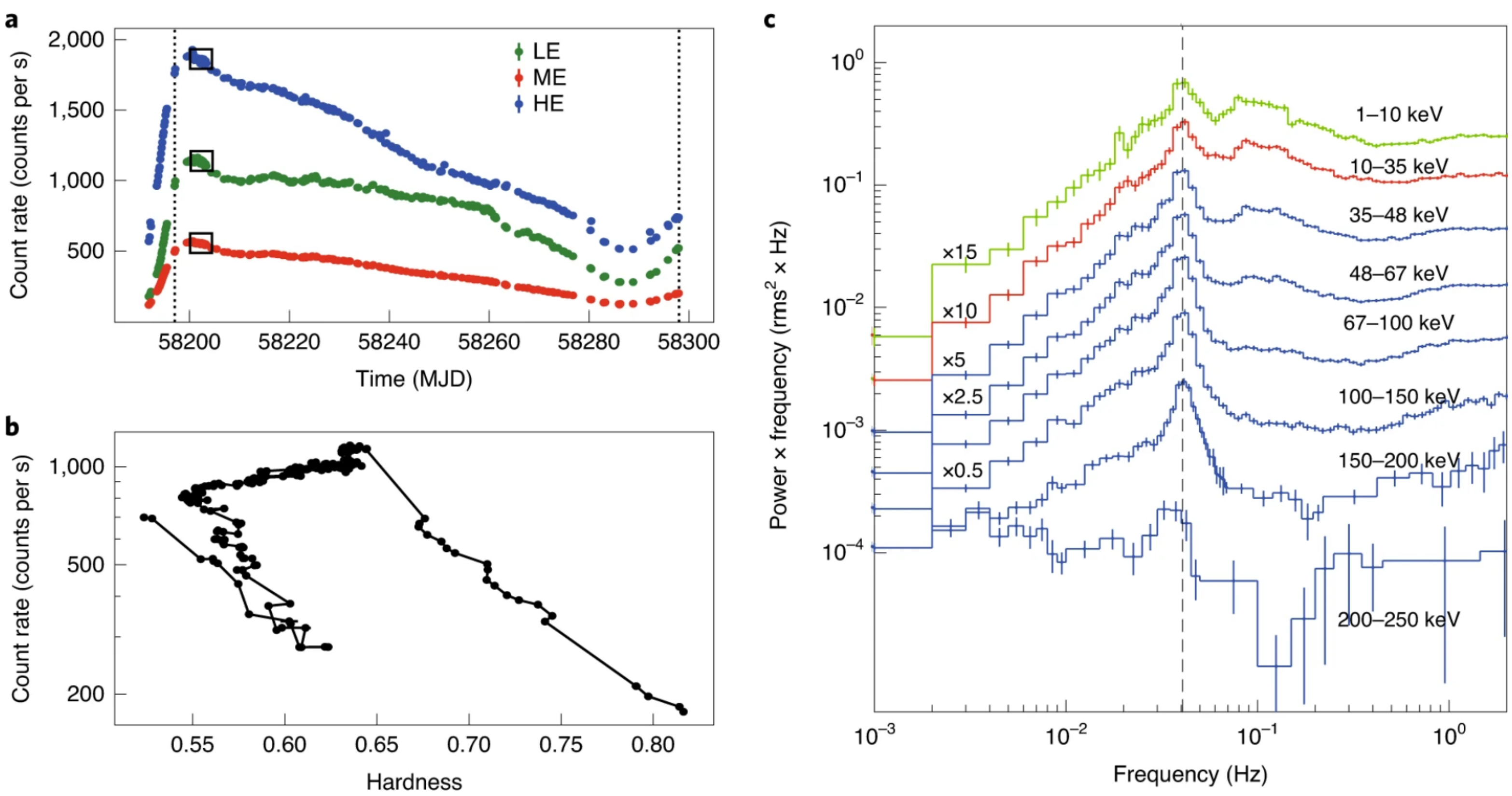
Supermassive black hole
Weakly curved spacetime
(~Solar)

TESTS OF GR PREDICTIONS IN THE STRONG FIELD REGIME OF GRAVITY.
COMPLEMENTARY TO GRAVITATIONAL WAVE EXPERIMENTS.

QPOs of BH binaries: < 30 keV → >200 keV

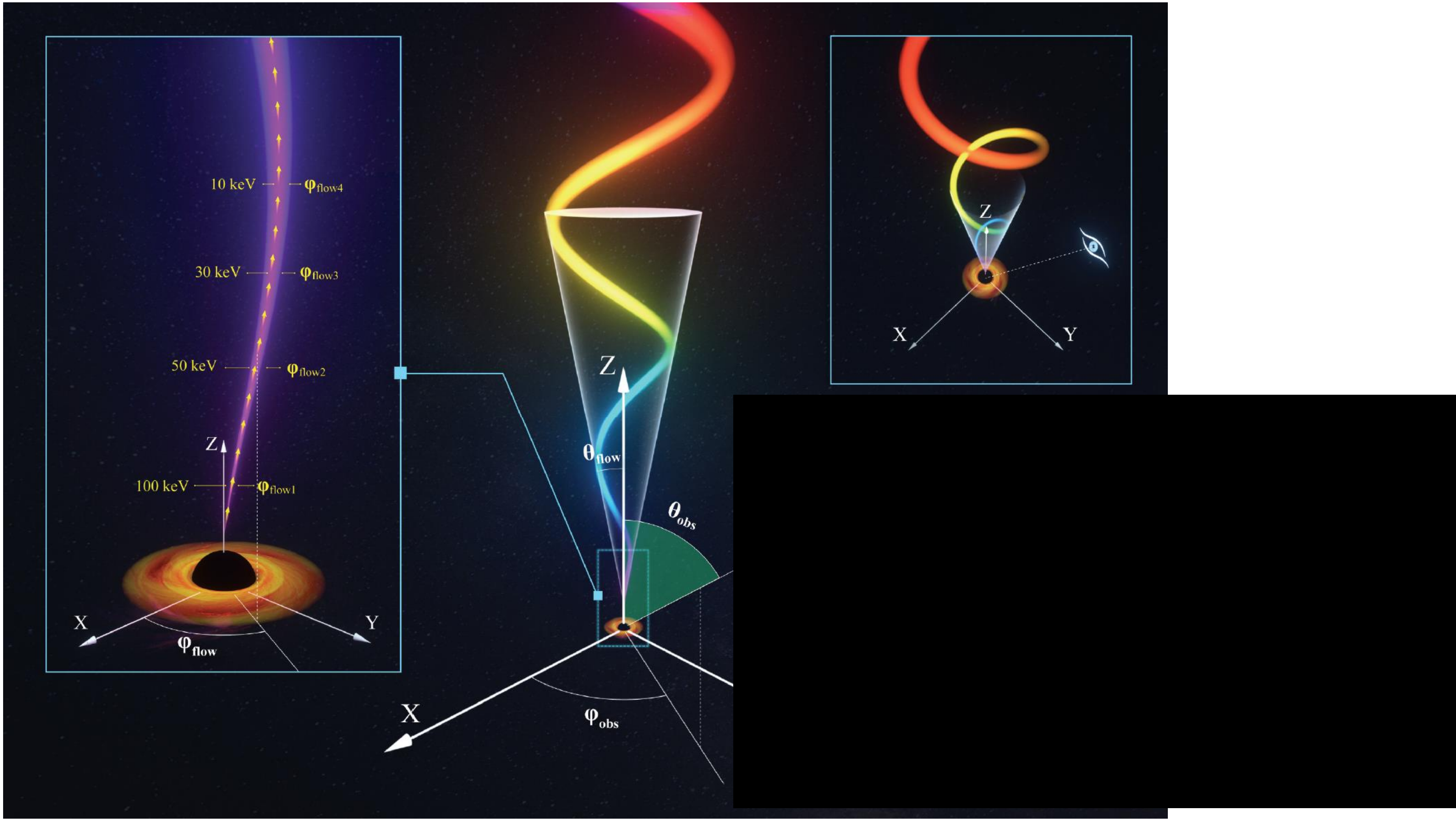
Fig. 1: Light curves, hardness–intensity diagram and power density spectra of MAXI J1820+070 in the X-ray hard state.

From: Discovery of oscillations above 200 keV in a black hole X-ray binary with Insight-HXMT



Ma, Tao, SNZ+ 2021, Nature Astronomy

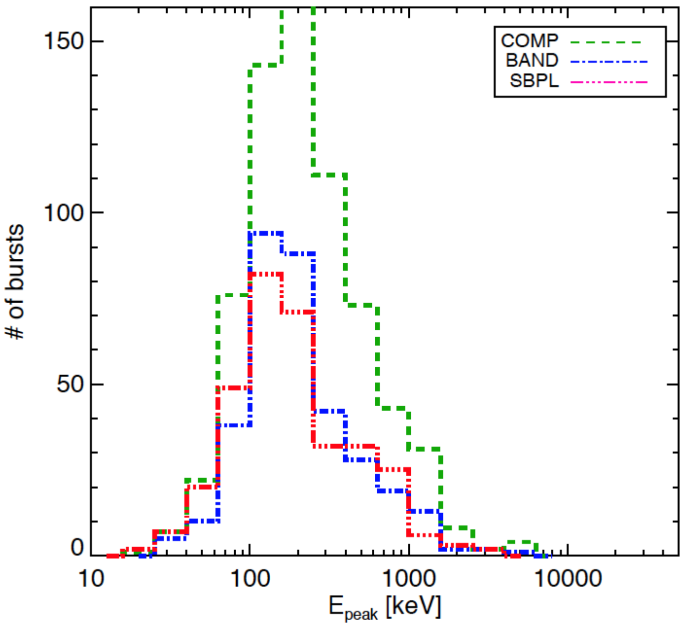
New model of BH QPOs: L-T precession Jet



Ma et al. 2020, Nature Astronomy

Dedicated working mode for GRB

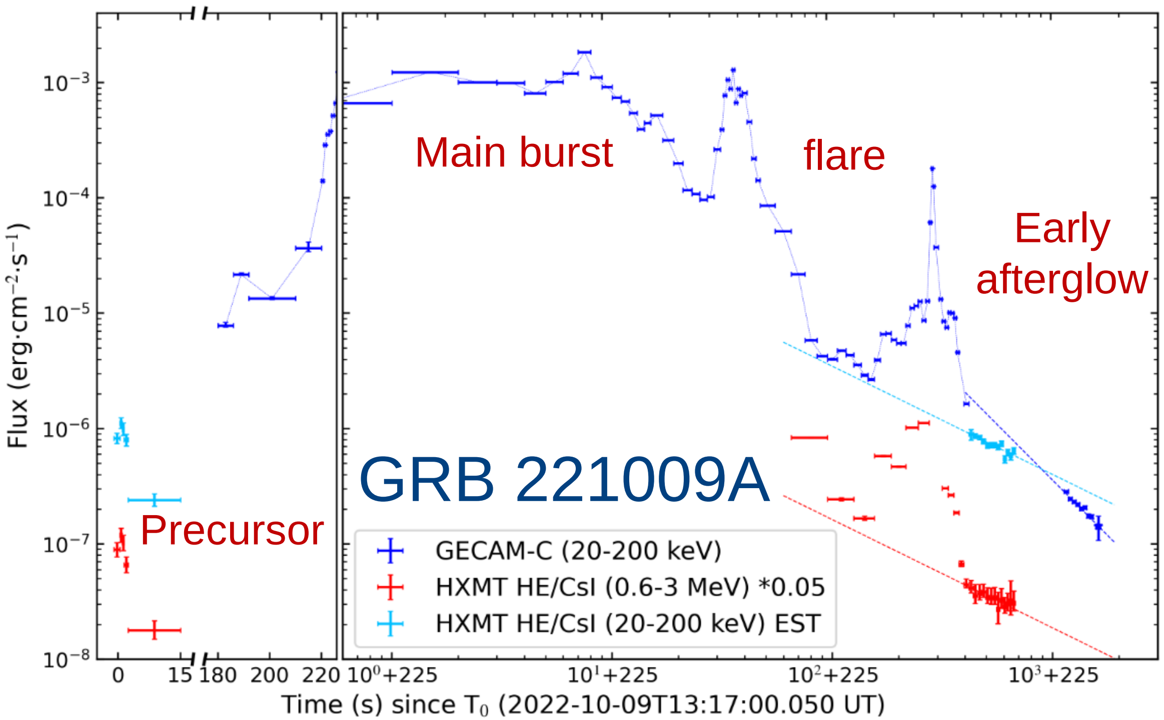
Working Mode	NaI energy band (keV)	CsI energy band (keV)	Detector Setting
Regular mode	20-250	40-600	Normal HV
GRB/LG mode	100-1250	200-3000	Lower the PMT HV, turn off the AGC



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

The brightest GRB: 221009A



1 ☐ 2023ApJ...948L..12K 2023/05 cited: 14

GRANDMA and HXMT Observations of GRB 221009A: The Standard Luminosity Afterglow of a Hyperluminous Gamma-Ray Burst-In Gedenken an David Alexander Kann

Kann, D. A.; Agayeva, S.; Aivazyan, V. *and 113 more*

2 ☐ 2023arXiv230301203A 2023/03 cited: 16

Insight-HXMT and GECAM-C observations of the brightest-of-all-time GRB 221009A

An, Zheng-Hua; Antier, S.; Bi, Xing-Zi *and 175 more*

HXMT and GECAM accurately observed the GRB: precursor, main burst, flare & early afterglow.

1. Brightest > 50 times
2. Largest isotropic energy 1.5×10^{55} erg
3. Early afterglow break: very narrow jet~0.7°
4. Jet corrected energy 10^{51} erg: normal
5. Also VHE gamma-rays detected by LHAASO

Early jet break: 950±50 s & highest E_{iso}~1.5×10^{55} erg

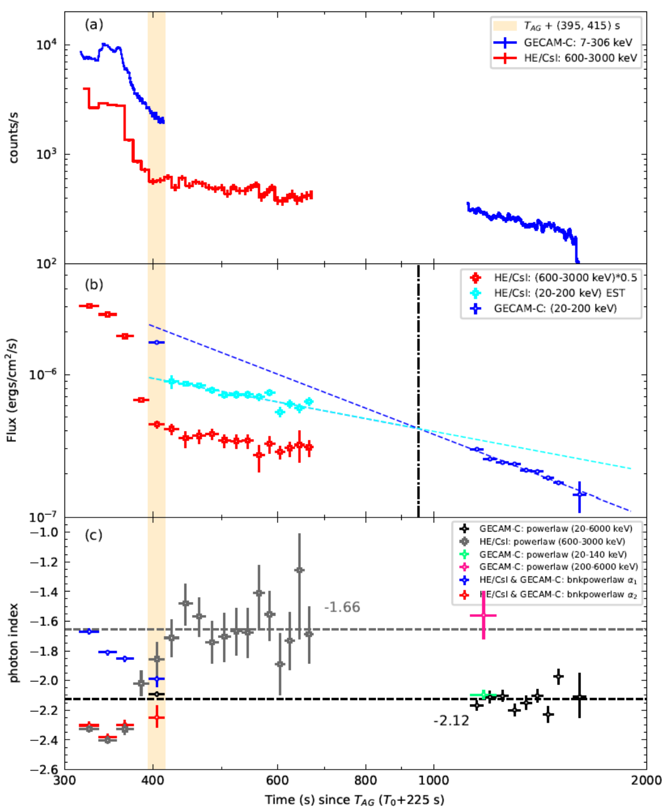


Figure 4: Evolution of light curve (Panel a), energy flux (Panel b) and photon index (Panel c) from flare-dominated phase to afterglow-dominated phase of GRB 221009A. The dashed lines are fit results to the HE/CsI light curve from T_0+600 s to T_0+900 s and GECAM-C light curve from T_0+1300 s to T_0+1860 s. The jet break time is estimated from a joint fit with broken power-law to the estimated 20-200 keV flux from T_0+600 s to T_0+900 s and the measured 20-200 keV flux from T_0+1300 s to T_0+1860 s.

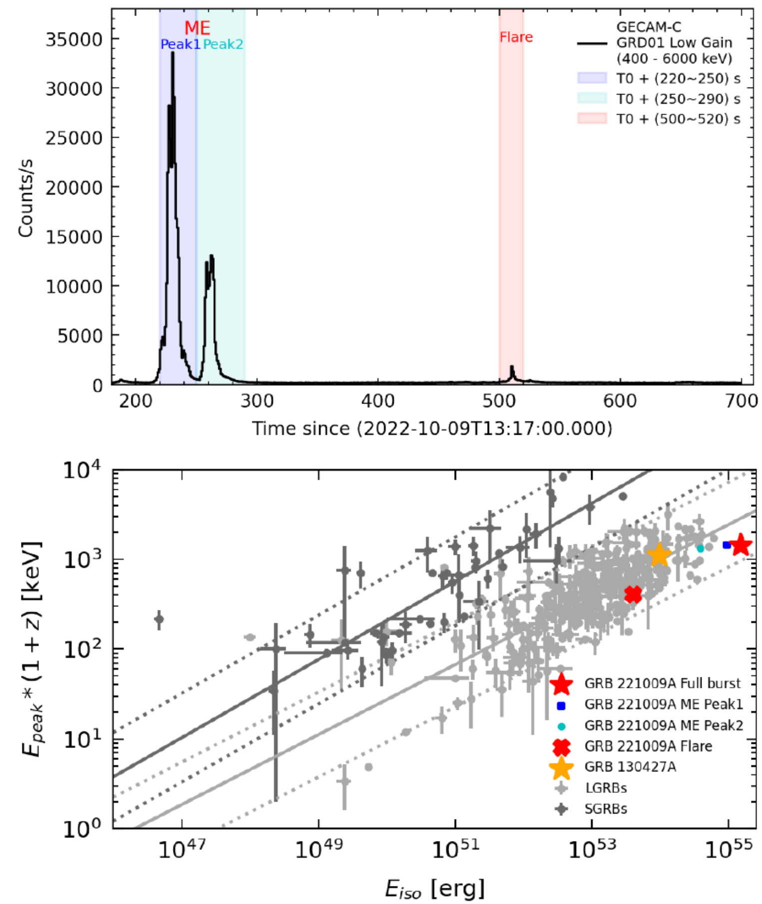
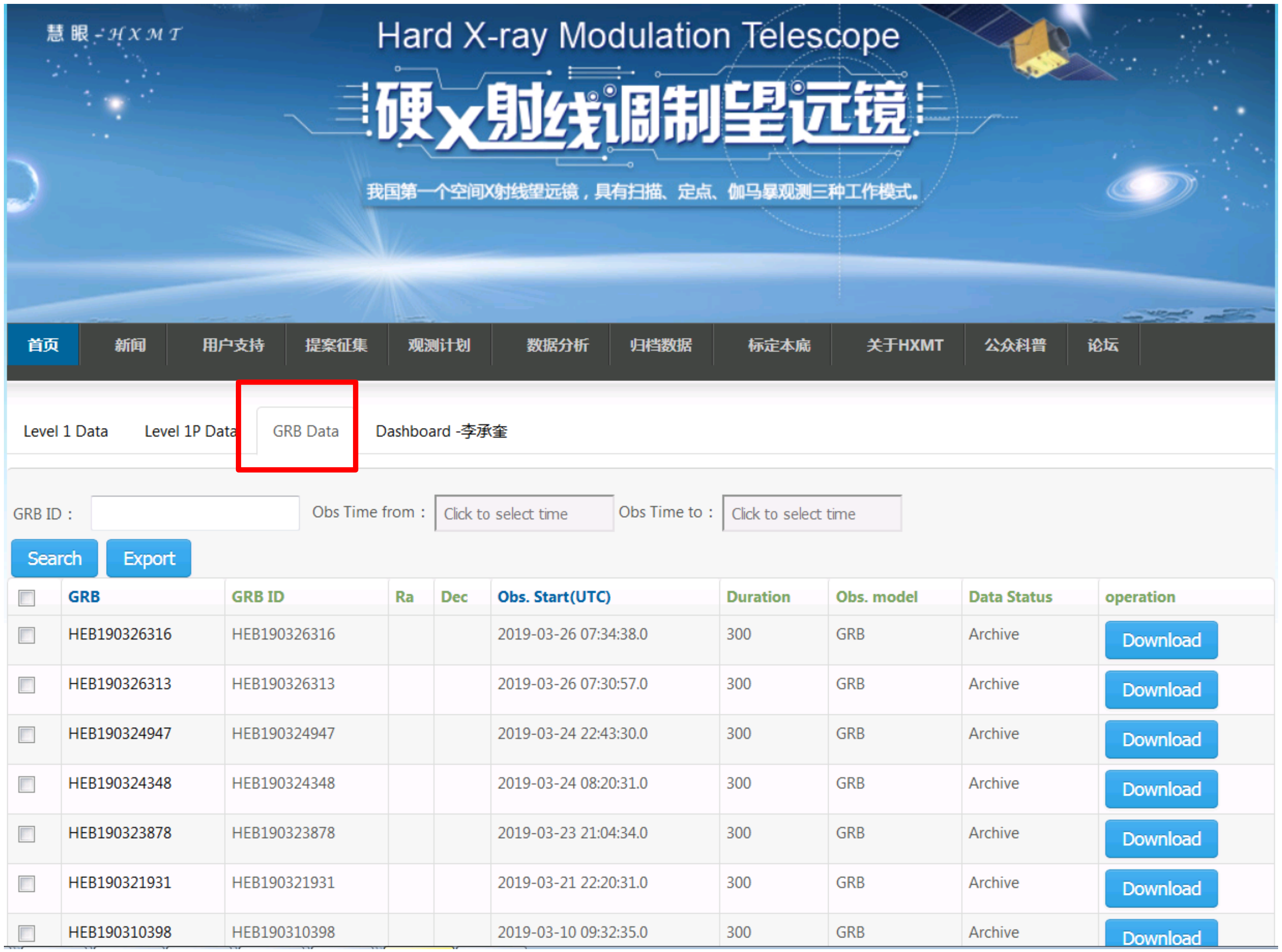


Figure 5: **Top Panel:** GECAM-C/GRD01 Low Gain light curve of GRB 221009A. **Bottom Panel:** Peak energy E_p and isotropic energy E_{iso} for GRB 221009A. The results for the two peaks in ME (Peak-1 and Peak-2) and the bright part of flare are also shown.

Insight-HXMT GRB public data products

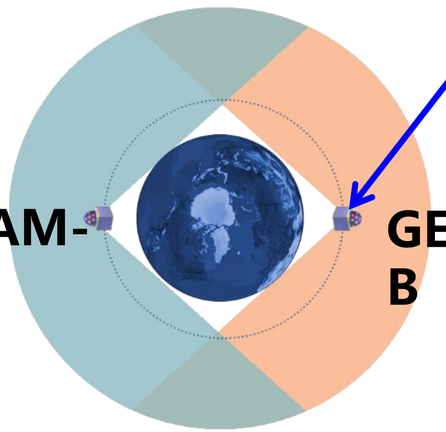


	GRB	GRB ID	Ra	Dec	Obs. Start(UTC)	Duration	Obs. model	Data Status	operation
	HEB190326316	HEB190326316			2019-03-26 07:34:38.0	300	GRB	Archive	Download
	HEB190326313	HEB190326313			2019-03-26 07:30:57.0	300	GRB	Archive	Download
	HEB190324947	HEB190324947			2019-03-24 22:43:30.0	300	GRB	Archive	Download
	HEB190324348	HEB190324348			2019-03-24 08:20:31.0	300	GRB	Archive	Download
	HEB190323878	HEB190323878			2019-03-23 21:04:34.0	300	GRB	Archive	Download
	HEB190321931	HEB190321931			2019-03-21 22:20:31.0	300	GRB	Archive	Download
	HEB190310398	HEB190310398			2019-03-10 09:32:35.0	300	GRB	Archive	Download

http://hsuc.ihep.ac.cn/web/hxmtdata/grb

GECAM

Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor



GECAM satellite (~160 kg for each)

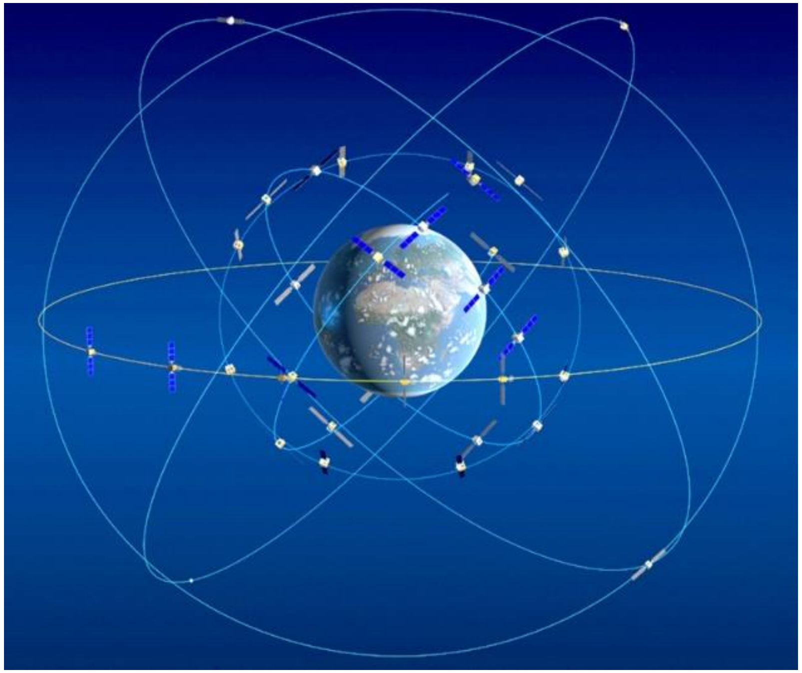
Launched on Dec 10, 2020

- Characteristics
  - **FOV:** 100% all-sky
  - **Energy band:** 6 keV – 5 MeV
  - **Sensitivity:** <2E-8 erg/cm^2/s
  - **Localization:** <1 deg (1-σ stat., 1E-5 erg/cm^2)
- Real-time alerts
  - Trigger time, localization, duration, spectrum, etc.
  - Latency: 1-3 minutes

PI: Shaolin Xiong (IHEP)

Near Real-time alerts with Beidou Navigation system

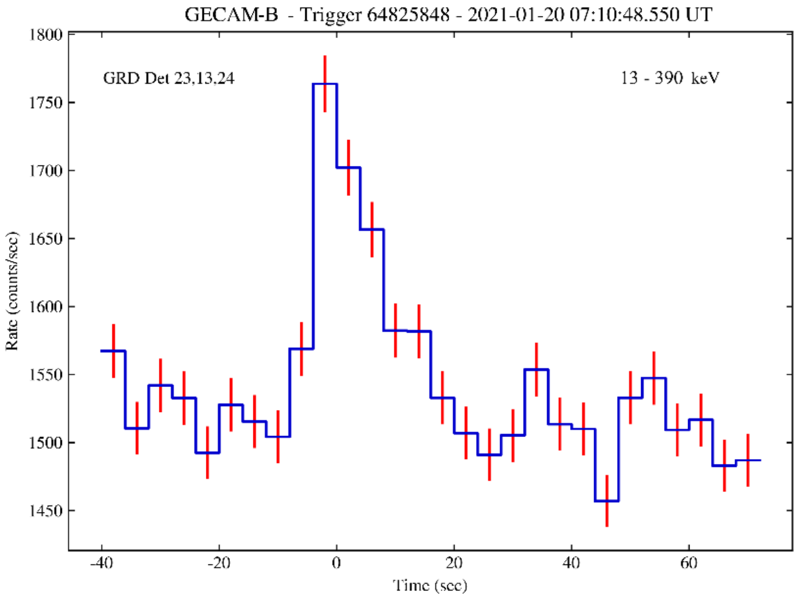
- In-flight alerts
  - Content: Trigger time, location, duration, spectrum, etc
  - Latency**: 1-3 minutes**
- **Ground automatic alerts**
  - Content: refined location, duration, refined trigger classification, etc.
  - Latency: **10-30 minutes**
- Final **alerts**
  - Content: final results of GECAM
  - Latency: ~**hours**



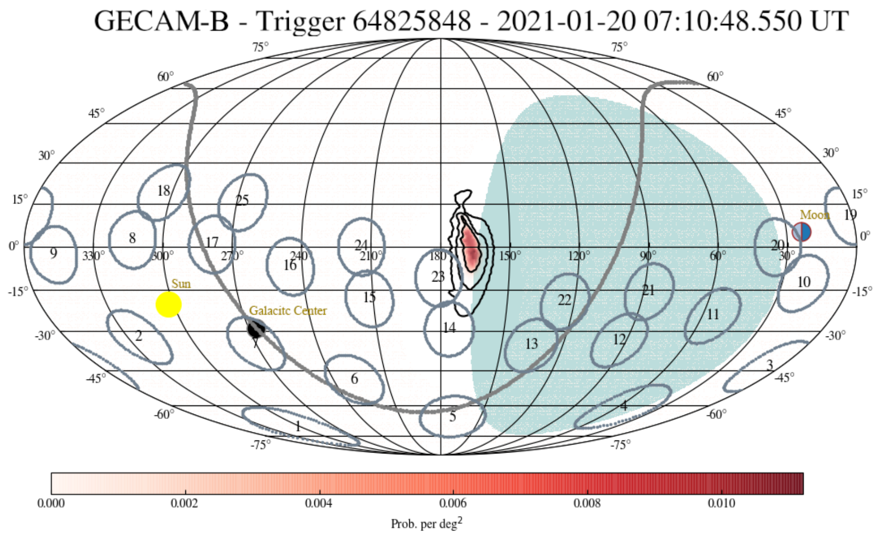
GECAM-C has been launched on July 27, 2022;
GECAM-D will be launched soon.

The first GECAM GRB with near real-time alert

- BeiDou Navigation System (BDS)
  - Time latency ~ 60 seconds



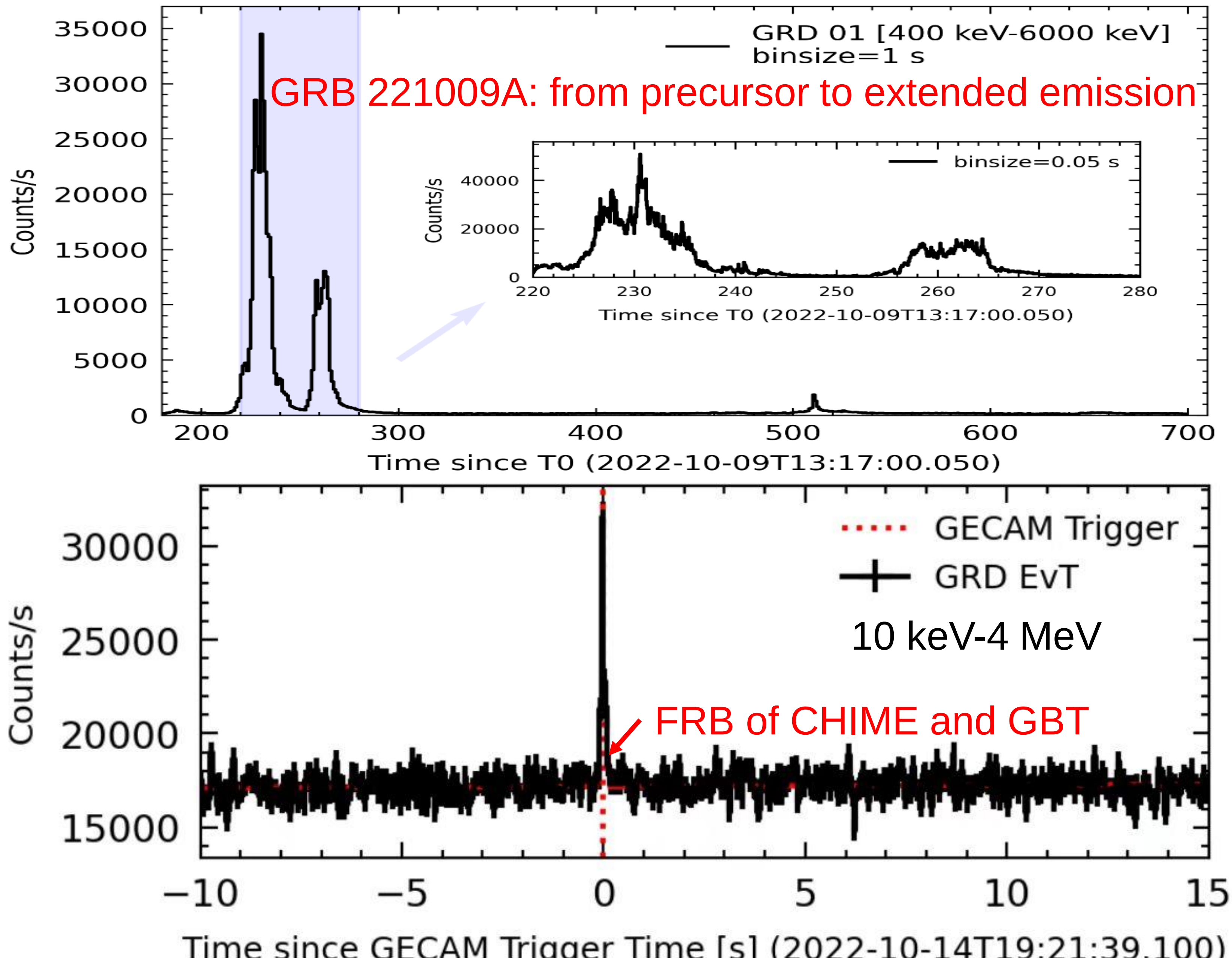
Near real-time Light curve



Ground location with the BDS alert data

GECAM-C has been launched on July 27, 2022;
GECAM-D will be launched soon.

GRB 221009A and FRB/X-ray of SGR1935 with GECAM

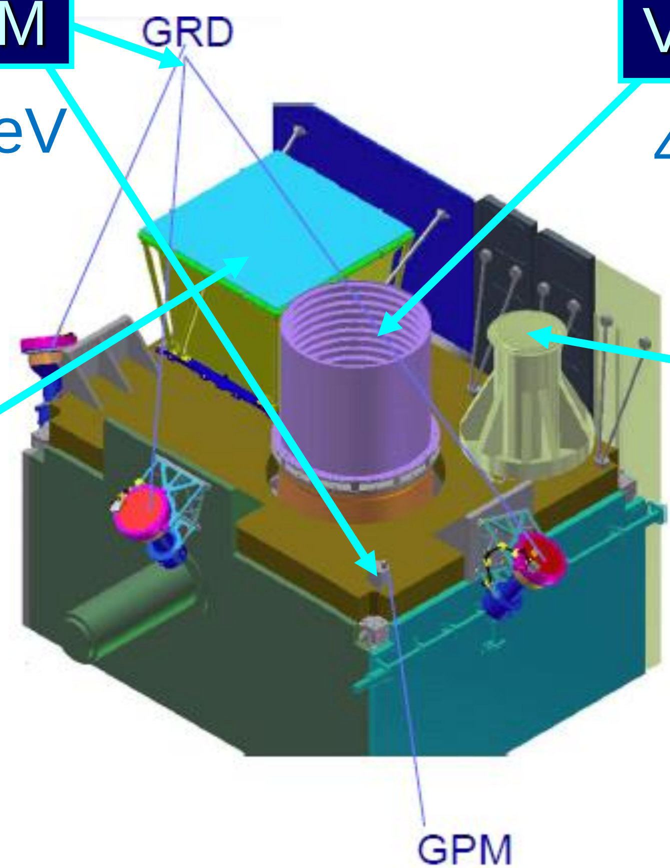


SVOM (Space Variable Object Monitor)

IHEP

GRM
30 keV-5 MeV

VT
400-650 nm, 650-950 n



Eclairs
4-250 keV

MXT
0.3-5 keV

PIs: Jianyan Wei,
National Astronomical
Observatories of China;
Bertrand Cordier, CEA, France
Launch: 2024

PI: Prof. J.Y. Wei, NAOC

450-900 nm
GWAC

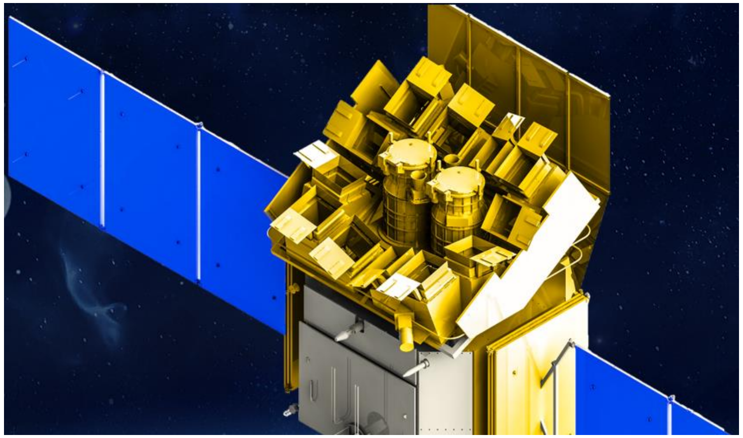
400-1700 nm
GFTs

Scientific Objectives of SVOM

GRB phenomenon	• Diversity and unity of GRBs
GRB physics	• Acceleration and nature of the relativistic jet • Radiation processes • The early afterglow and the reverse shock
GRB progenitors	• The GRB-supernova connection • Short GRB progenitors
Cosmology	• Cosmological lighthouses (absorption systems) • Host galaxies • Tracing star formation • Re-ionization of the universe • Cosmological parameters
Fundamental physics	• Origin of high-energy cosmic rays • Probing Lorentz invariance • Short GRBs and gravitational waves

The Einstein Probe (EP) mission

- **The first mission that uses Lobster-eye optics to monitor transients in the soft X-ray band.**
- **Proposed in 2012, selected in the end of 2017**
- **Launch date: ~2023.12.31**



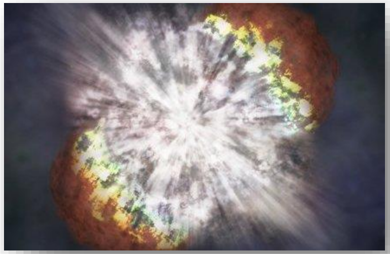
Mission Features

- Very wide FoV 1.1 sr (3600 sq. deg.) grasp: ~10,000 $deg^2.cm^2$
- Good angular resolution (~5') and positioning accuracy (<1')
- Soft X-ray band: 0.5-5 keV
- Sensitivity: **>1 order of magnitude higher** than current telescoeps
- Autonomous X-ray follow-up (<10 arcsec localisation)
- Fast alert data downlink and fast uplink for ToO (TBC)

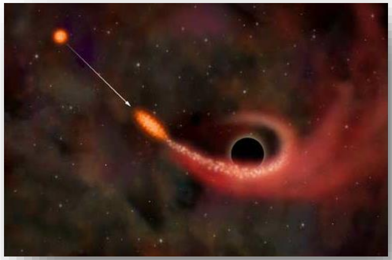
PI: Prof. Weimin Yuan, National Astronomical Observatories of China

Main science goals of the EP mission

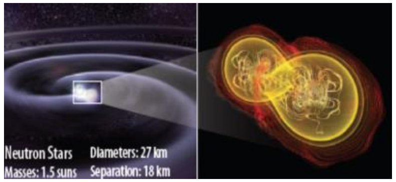
Carry out **systematic survey** of soft X-ray transients and variability of X-ray sources at unprecedented sensitivity and high cadence



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

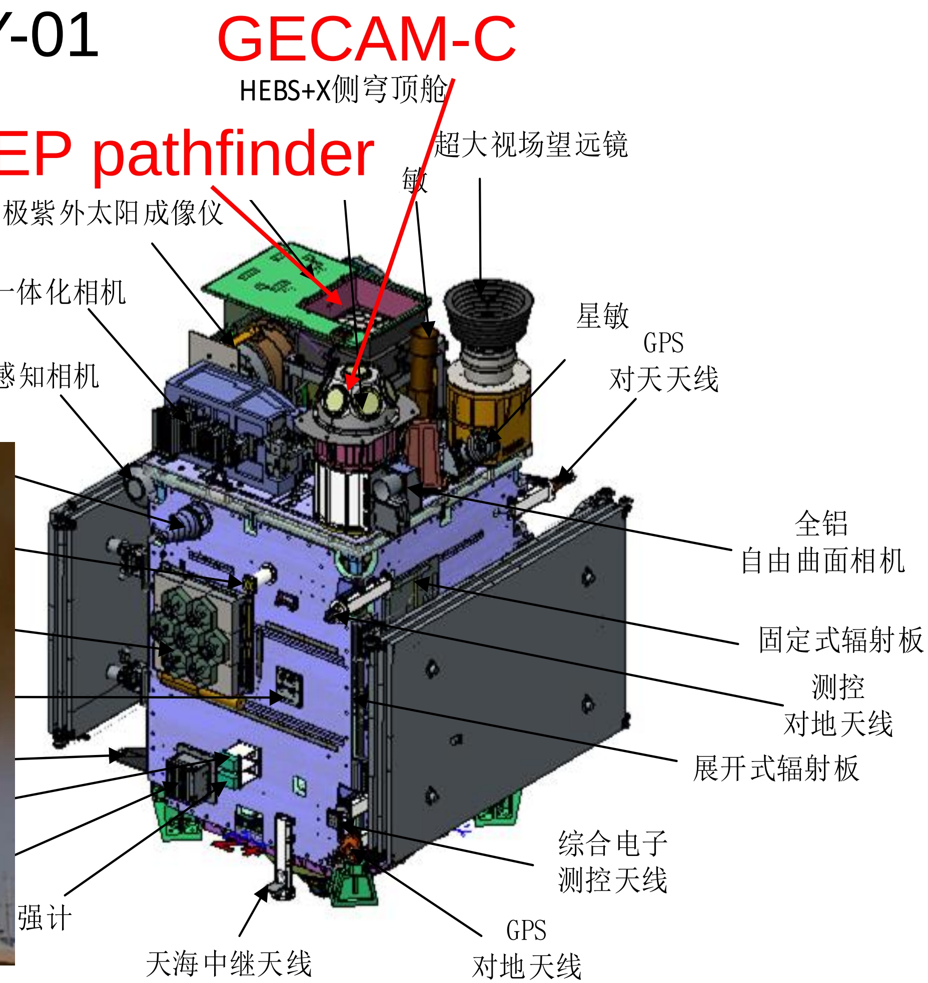


Detect and localize the **electromagnetic-wave sources of gravitational-wave events** by synergy with gravitational-wave detectors



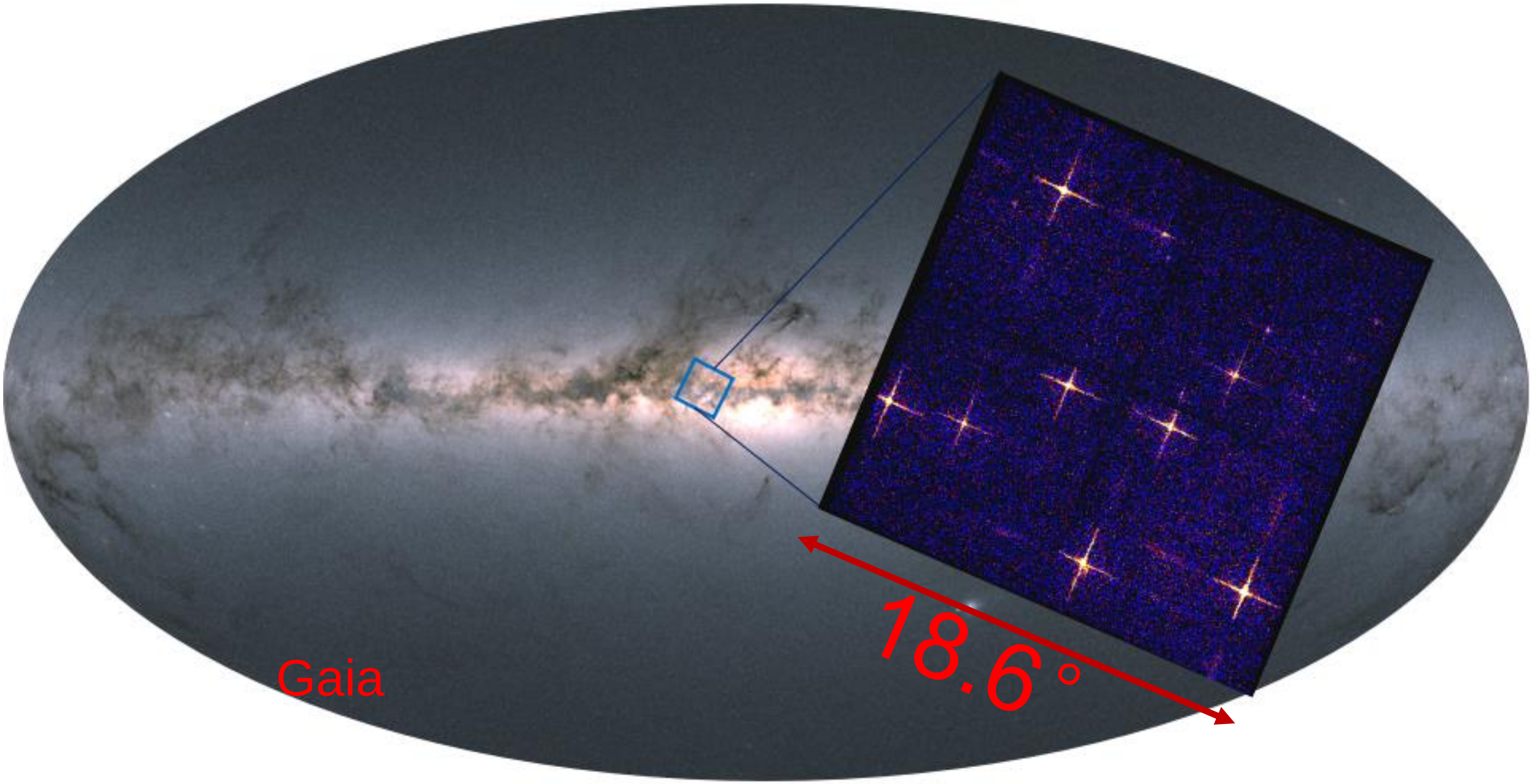
EP pathfinder
focusing X-ray telescope with the largest FoV

On New Technology Satellite SY-01
- ✓ Launched on July 27, 2022
- ✓ FoV:340 square degrees
- ✓ Co-aligned with GECAM-C



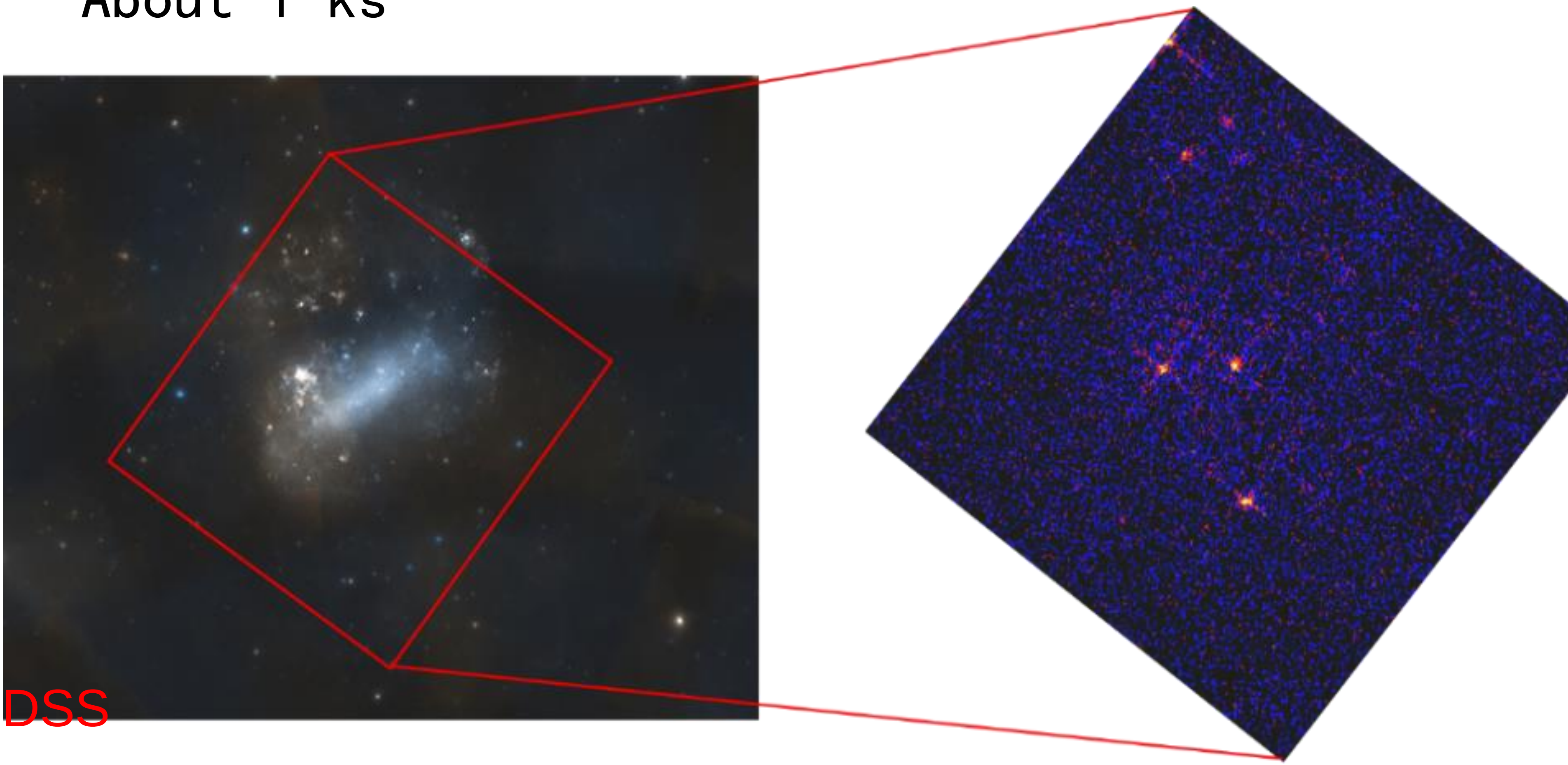
Galactic center image

About 1 ks



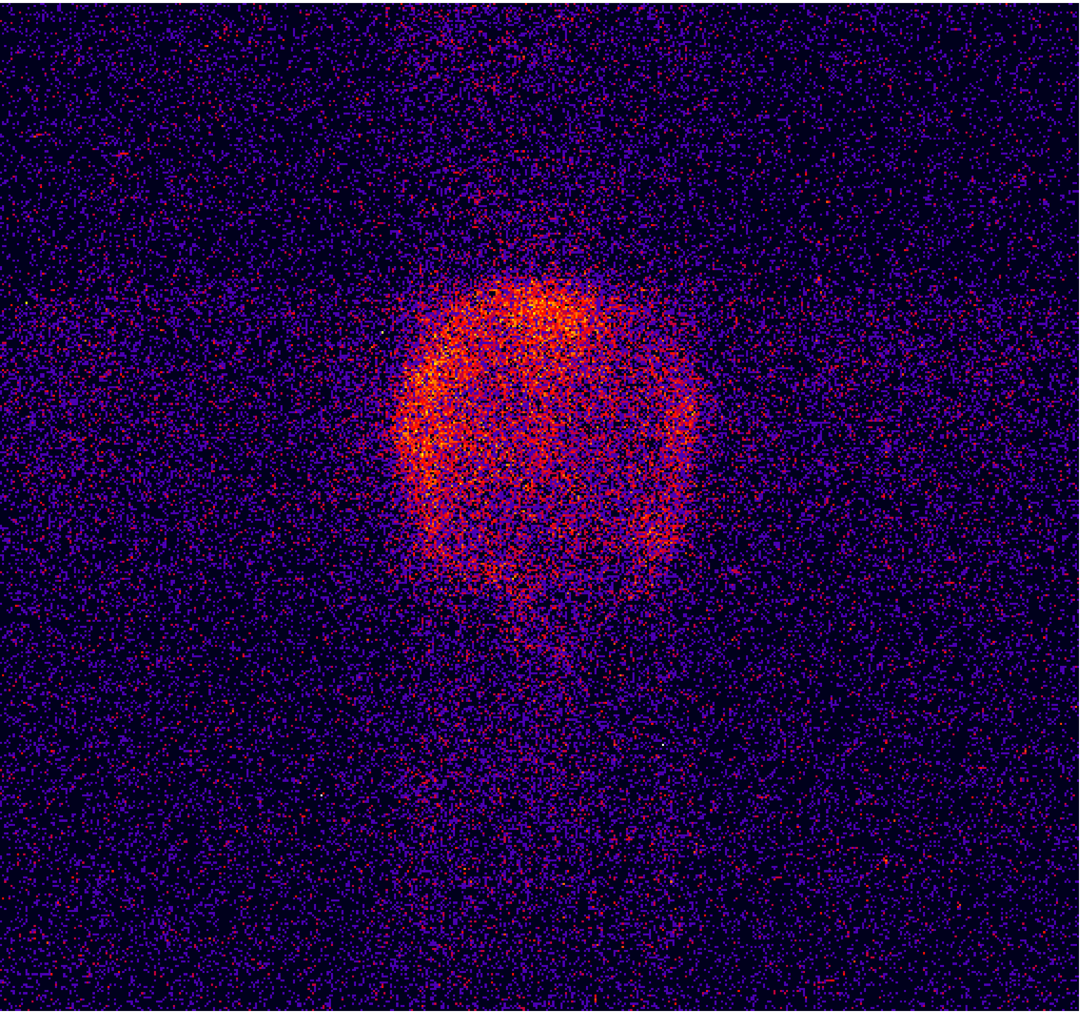
LMC

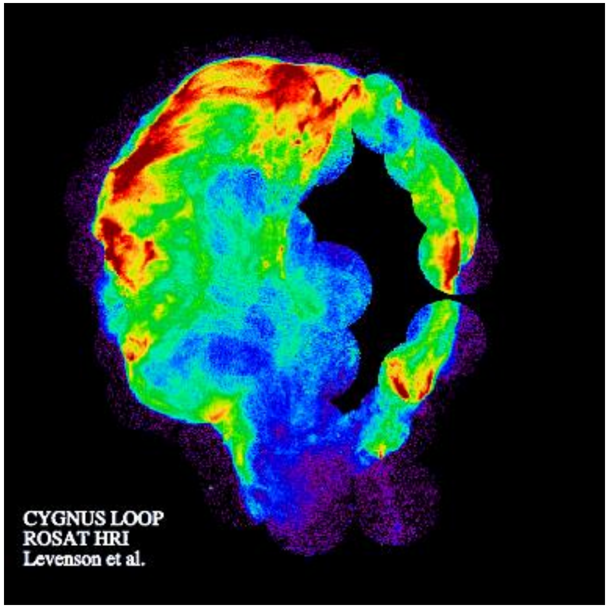
About 1 ks



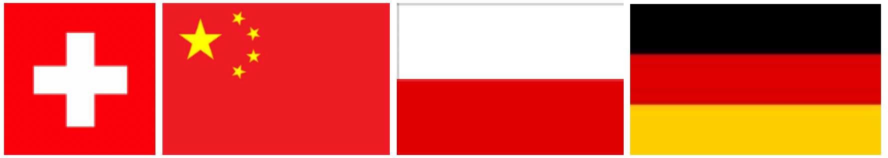
Cygnus Loop

About 1 ks





The POLAR-2 experiment



- Enhanced GRB polarimeter, successor of POLAR
- Officially selected by CSS through UNOOSA in 2019, aims to launch around 2025

Announcement of selection Jun./2019

UNITED NATIONS
Office for Outer Space Affairs

CMS

United Nations/China Cooperation on the Utilization of the China Space Station (CSS)

联合国/中国围绕中国空间站应用开展合作

Selected Experiment Projects to be executed on board the CSS for the 1st Cycle

Announced on the occasion of the 62nd Session of the Committee on the Peaceful Uses of Outer Space

12 June 2019 Vienna, Austria

第一轮合作入选项目

2019 年 6 月 12 日在奥地利维也纳举行的第 62 届和平利用外空委员会大会期间发布

I. Fully accepted experiment projects:

完全入选项目

No.1: POLAR-2: Gamma-Ray Burst Polarimetry on the China Space Station

Building on the previous investigation on China's TG-2 space lab, this project aims to answer the most important open questions in astrophysics regarding the nature of Gamma-Ray Bursts (GRBs) by using the most promising investigation approach of polarization measurements allowing to observe even the weakest gamma-ray transients, such as those connected to gravitational waves.

It is an experiment project in astronomy in space. It was applied and will be implemented by four institutions from four countries, which are: The University of Geneva from Switzerland, the National Center for Nuclear Research of Poland, the Max Plank Institute for Extra-terrestrial Physics of Germany, and the Institute of High Energy Physics of Chinese Academy of Sciences.

第 1 个项目：POLAR-2：中国空间站上的伽玛暴偏振探测仪

Nature report

nature

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NEWS · 17 JUNE 2019

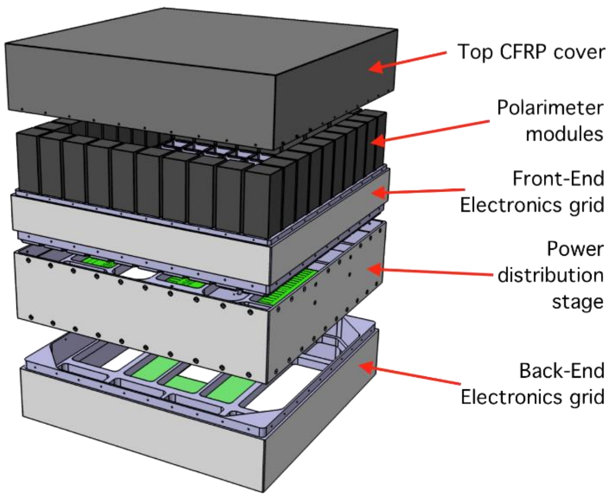
China reveals scientific experiments for its next space station

Other winners include a detector called POLAR-2, a more powerful follow-up to a sensor launched on Tiangong-2 to study the polarization of energetic γ-ray bursts from distant cosmic phenomena. POLAR-2, which will be built by an international collaboration, could even allow astronomers to observe the weak radiation associated with sources of gravitational waves.

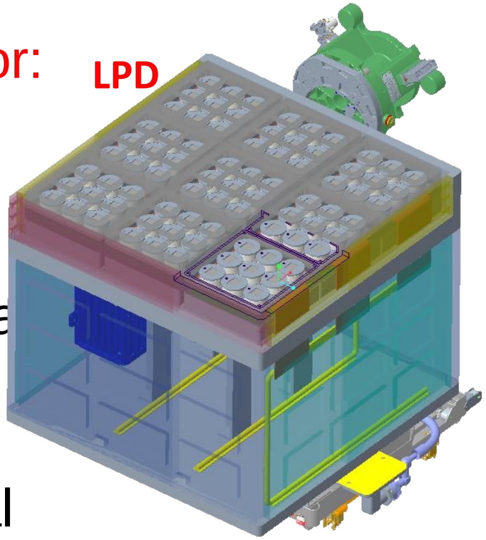
POLAR-2 current design of instruments

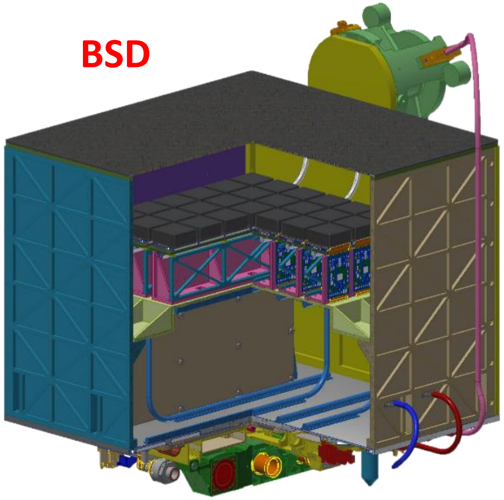
Polarimetry with largest FoV and broadest energy band

- ➢ High-energy Polarization Detector: HPD
- ➢ E-range for polarimetry: ~30-800 keV
- ➢ 100 modules, 6400 plastic scintillator bars
- ➢ Effective area: > 2000cm^2, > 1000cm^2 for Pol.
- ➢ FOV: ~50% sky
- ➢ Collaborations: UNIGE/IHEP/MPE/NCBJ
- ➢ Has been approved through United Nations



- ➢ Low-energy Polarization Detector: LPD, GXU, China
- \- ~2-10 keV X-ray polarimetry
- ➢ Broad energy-band Spectrum Detector: BSD, IHEP/CAS, China
- \- ~10-2000 keV for spectroscopy
- \- Accurate GRB localization: < 1°
- ➢ Status: under review for approval

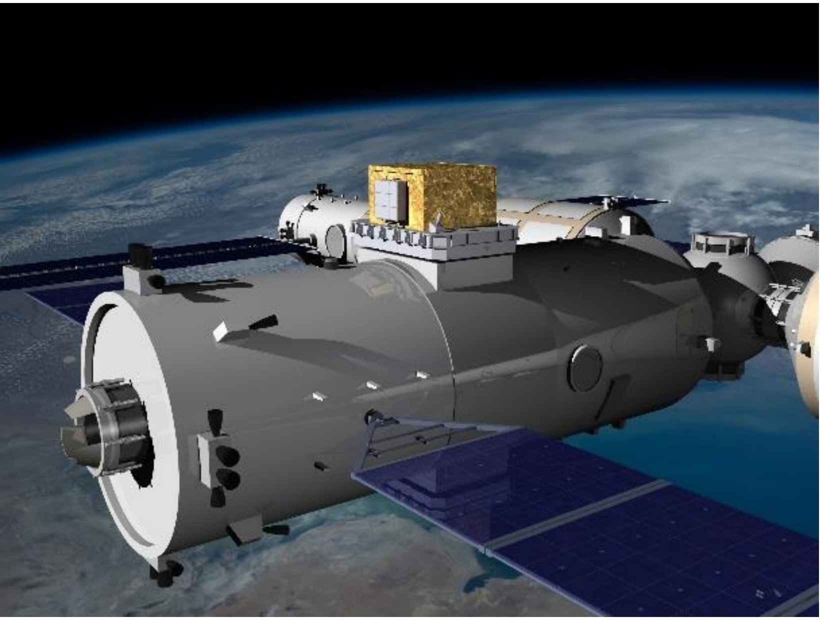


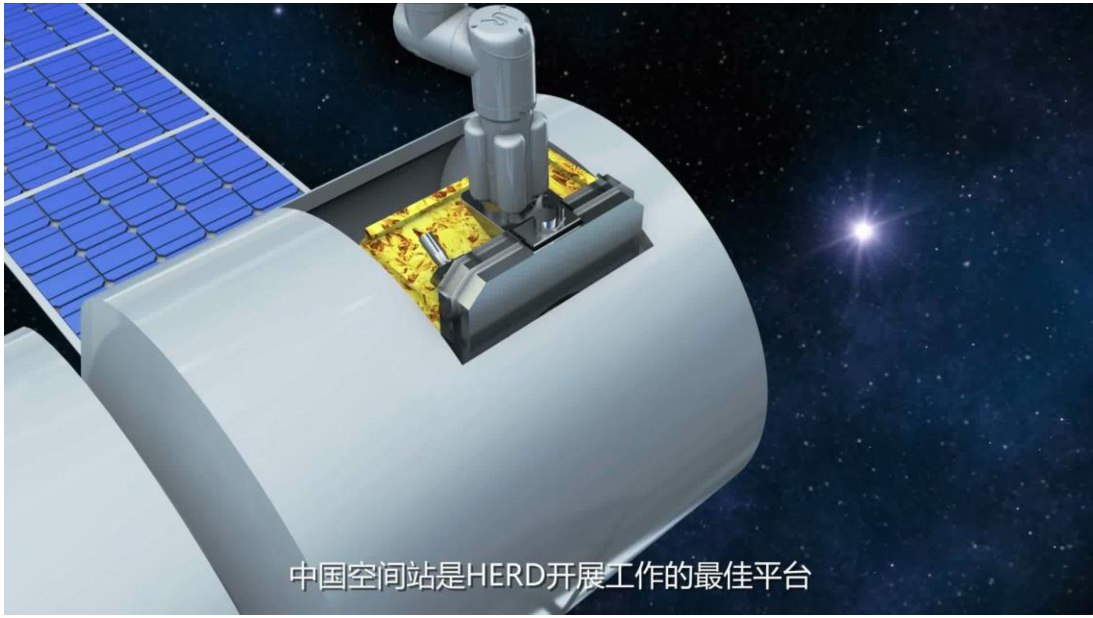


PIs: Shuang-Nan Zhang (IHEP), Xin Wu (UniGe)

High Energy cosmic-Ray Detection (HERD)

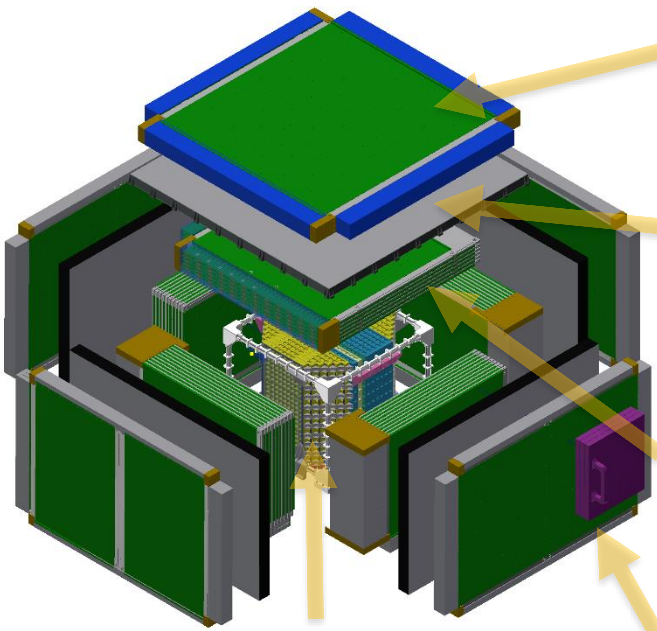
- HERD: flagship and landmark scientific experiment onboard the China's Space Station, China-led large international collaboration, ~2027
- Scientific goals
  - Dark matter search with high energy electrons and gamma-rays
  - Precise CR spectrum and composition measurements up to knee energy
  - Gamma-ray monitoring → trigger for CTA or other telescopes





(preliminary accommodation design, TBD)

HERD current baseline design



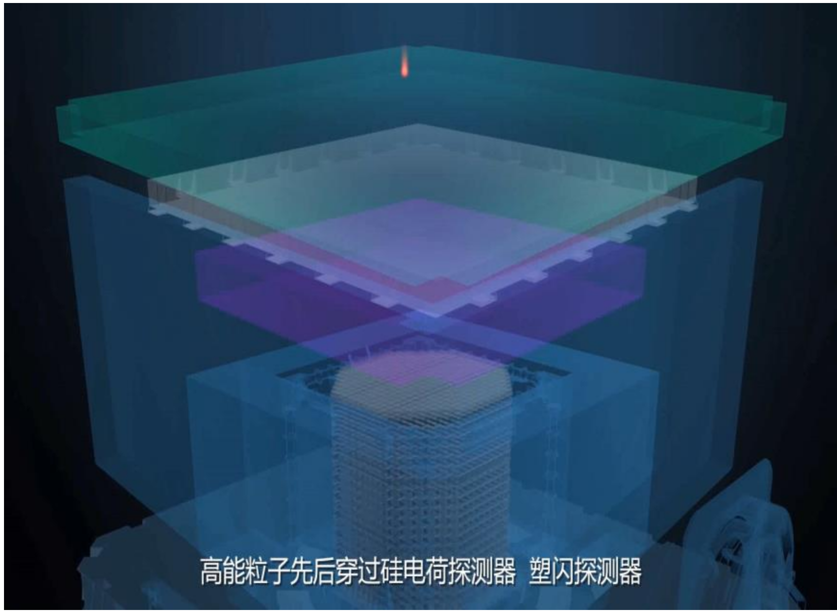
Silicon Strip Charge Detectors

Plastic Scintillators
e/γ ID
Charge

Fiber Tracker
Tracks
γ conversion

Transition Radiation Detector
TeV energy scale calibration

3D Imaging Calorimeter
Energy
Particle ID



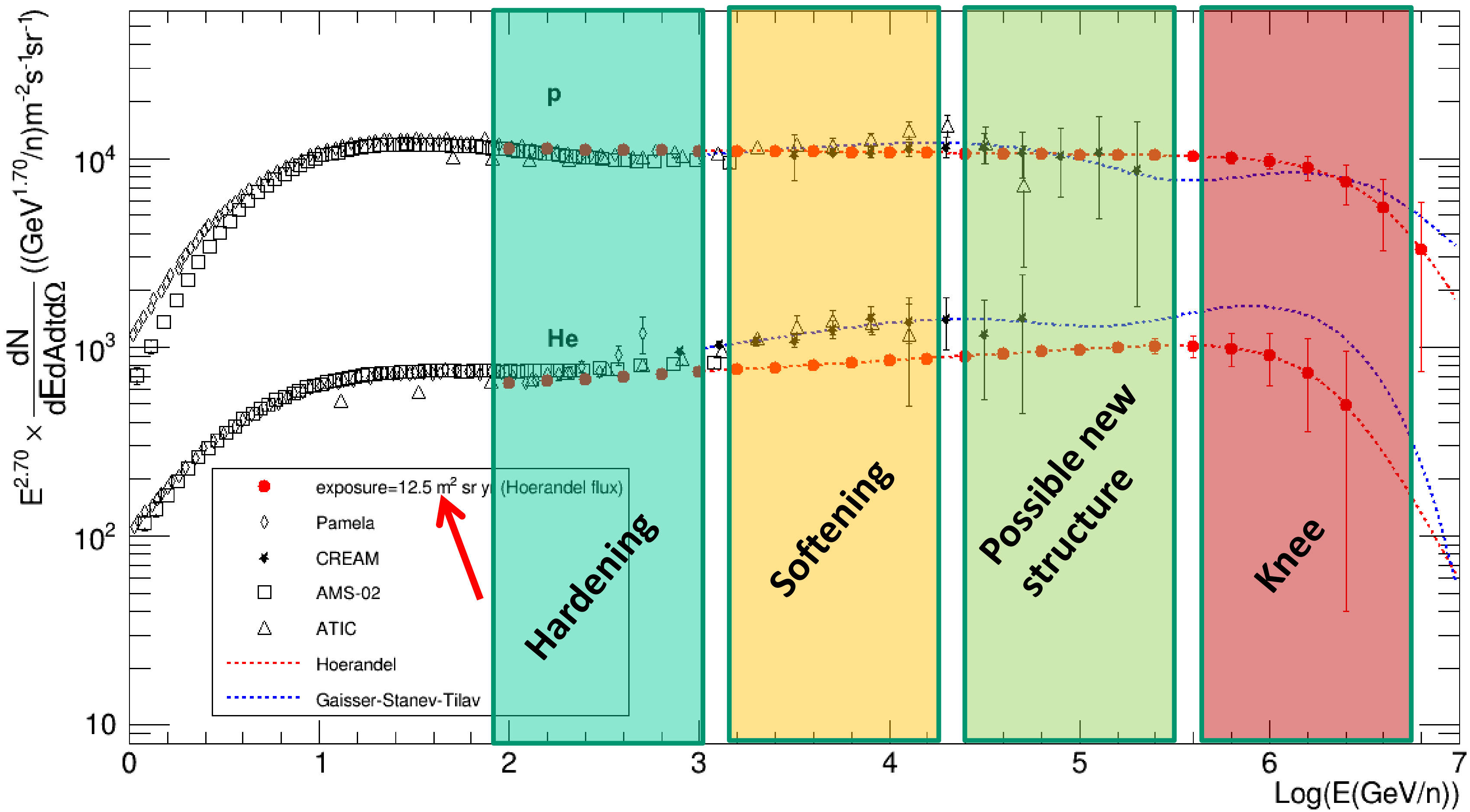
PI: Shuang-Nan Zhang (IHEP);
Europe Coordinator: Giovanni Ambrosi (INFN, Perugia)

HERD vs. other experiments

Experiment (time)	Energy (e/γ)	Energy (p)	ΔE/E (e/γ)	ΔE/E (p)	e/p ID	e accep. m^2sr	p accep. m^2sr
FERMI (2008)	1GeV-300GeV	30GeV-10TeV	10%	40%	10^3	0.9	<0.28
ISS-AMS02 (2011)	1GeV-1TeV	1GeV-1.8TeV	2%	-	10^6	0.12	0.12
ISS-CALET (2015)	1GeV-10TeV	50GeV-10TeV	2%	35%	10^5	0.12	--
DAMPE (2015)	5GeV-10TeV	40GeV-100TeV	≤1.5%	25-35%	$3*10^4$	0.3	0.04
HERD (~2027)	10GeV-100TeV 0.5GeV-100TeV (γ)	30GeV-PeV	1%	20%	10^6	>3 (10X DAMPE)	>2 (50X DAMPE)

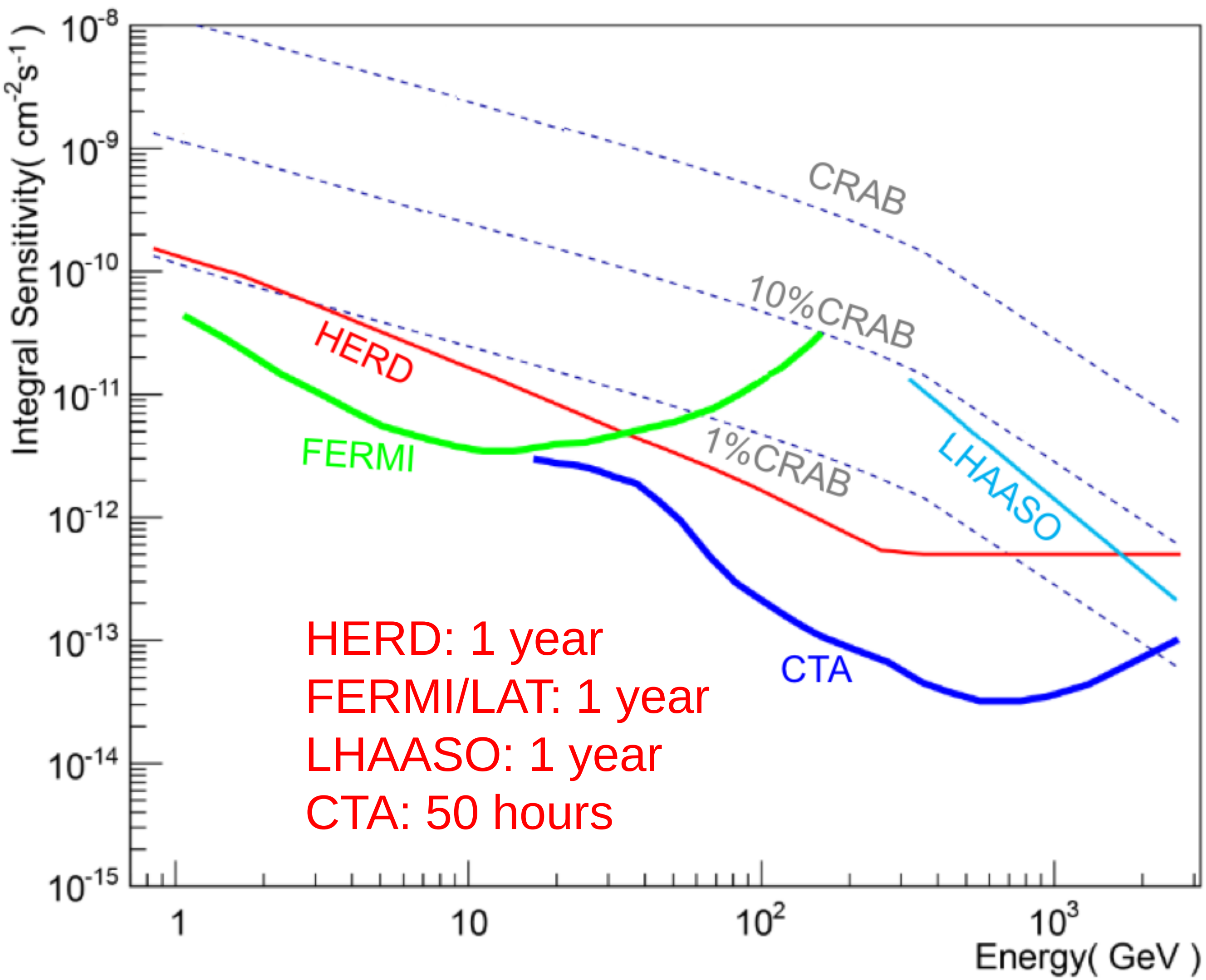
HERD is a next generation experiment, following AMS02 and DAMPE, with much better performance on direct high energy e, p, gamma-ray detection.

HERD Proton and Helium spectra (5 years , Hoerandel fluxes)



For the first time one single experiment will be able to probe all the funny structures in the CR spectra: Hardening, Softening, Possible new structure, Knee

HERD Gamma-ray sky survey

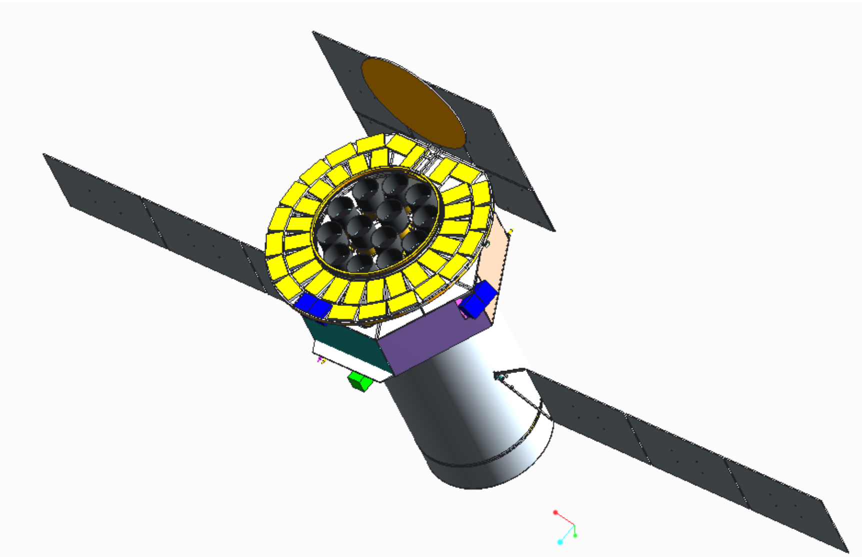


Expected HERD gamma-ray sky survey sensitivity (5σ)

New Themes of Space Science Program of China

- Extreme Universe: eXTP—enhanced X-ray Timing and Polarimetry observatory (the top-ranked mission in this theme)
- Ripples of Space-Time
- Habitable exoplanets
- Sun-Earth relation
- Biological and physical effects in space (microgravity)

eXTP: enhanced X-ray Timing and Polarimetry



Next Generation Flagship Observatory

- Important Sciences
  - Extreme gravity, magnetism, density
  - Neutron stars, black holes, etc
- Cutting-edge technology
  - Large eff. Area (~3.5 m^2@6 keV)
  - High spectral resolution (<180 eV@6 keV)
  - Polarimetry

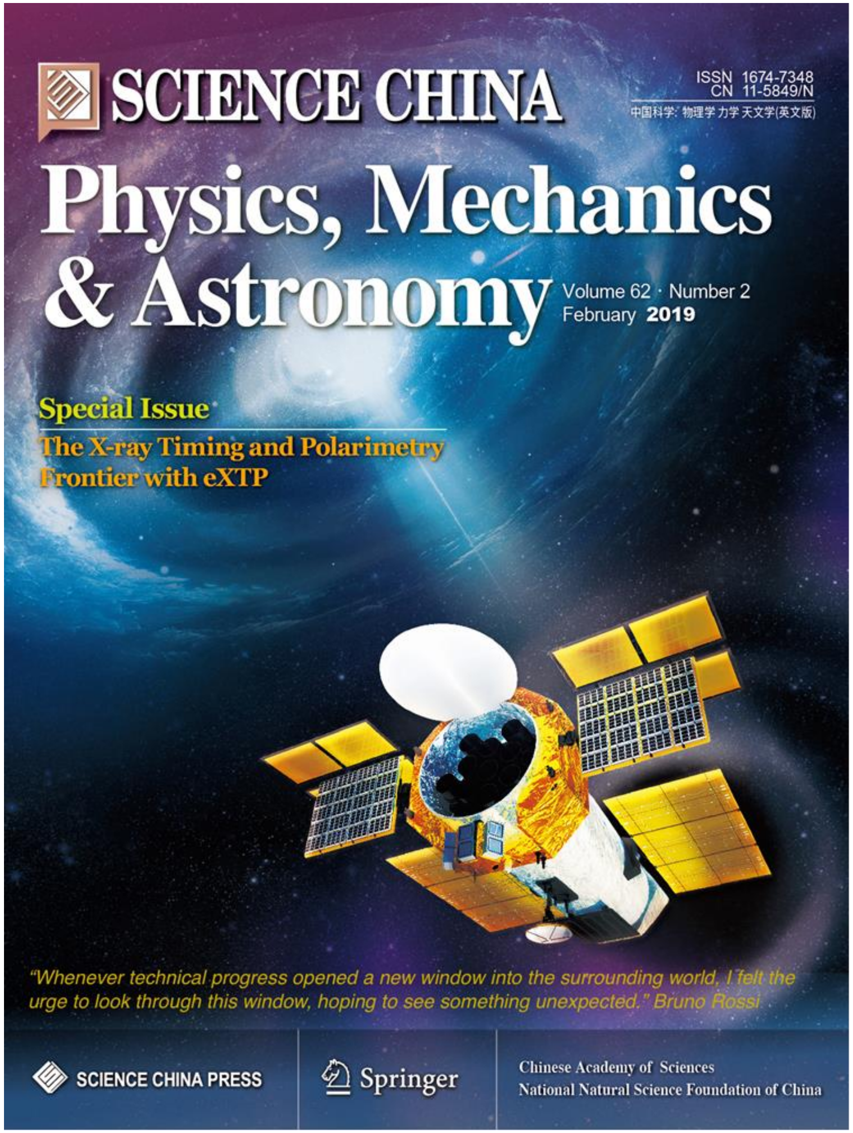
Payload	Configuration	Eff. area (m^2)
Spectroscopy Focusing Array (SFA)	9 telescopes	0.4m^2@6keV
Large Area Detector (LAD)	40 modules	3.4m^2@8keV
Polarimetry Focusing Array (PFA)	4 telescopes	500cm^2@2keV
Wide Field Monitor (WFM)	6 cameras	3.2 Sr （FOV）

PI: Shuang-Nan Zhang (IHEP); Europe: Marco Feroci (INAF, Rome)

White papers on eXTP

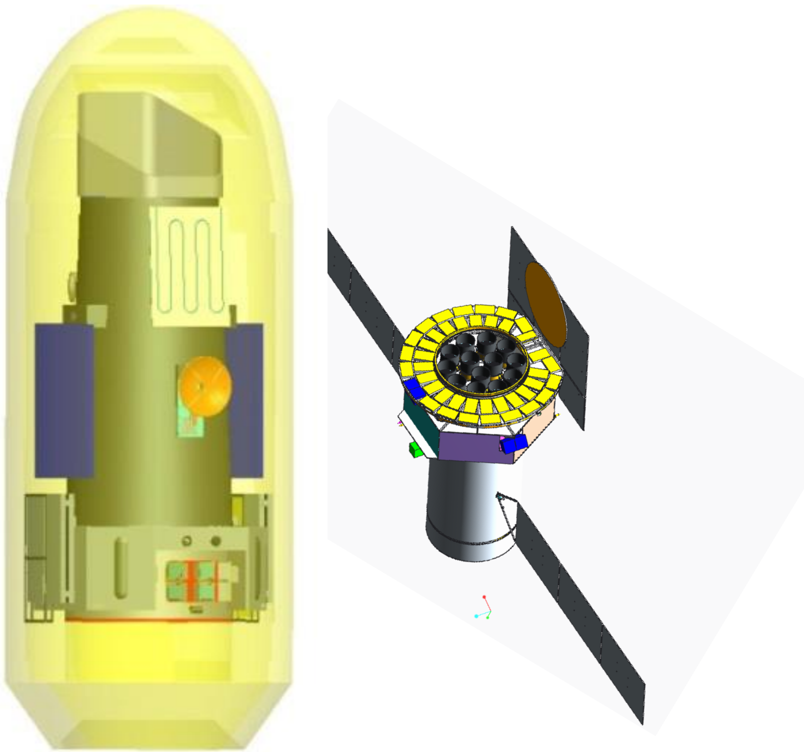
Five refereed papers have been published in a special issue of SCIENCE CHINA Physics, Mechanics & Astronomy, Feb. 2019

- S.-N. Zhang, A. Santangelo, M. Feroci, Y.P. Xu, et al., The enhanced X-ray Timing and Polarimetry mission - eXTP
- A. L. Watts, W.F. Yu, J. Poutanen, S. Zhang, et al., Dense matter with eXTP
- A. De Rosa, P. Uttley, L.J. Gou, Y. Liu, et al., Accretion in Strong Field Gravity with eXTP
- A. Santangelo, S. Zane, H. Feng, R.X. Xu, et al., Physics and Astrophysics of Strong Magnetic Field systems with eXTP
- J. J. M. in 't Zand, B. Enrico, J.L. Qu, X.D. Li, et al., Observatory science with eXTP



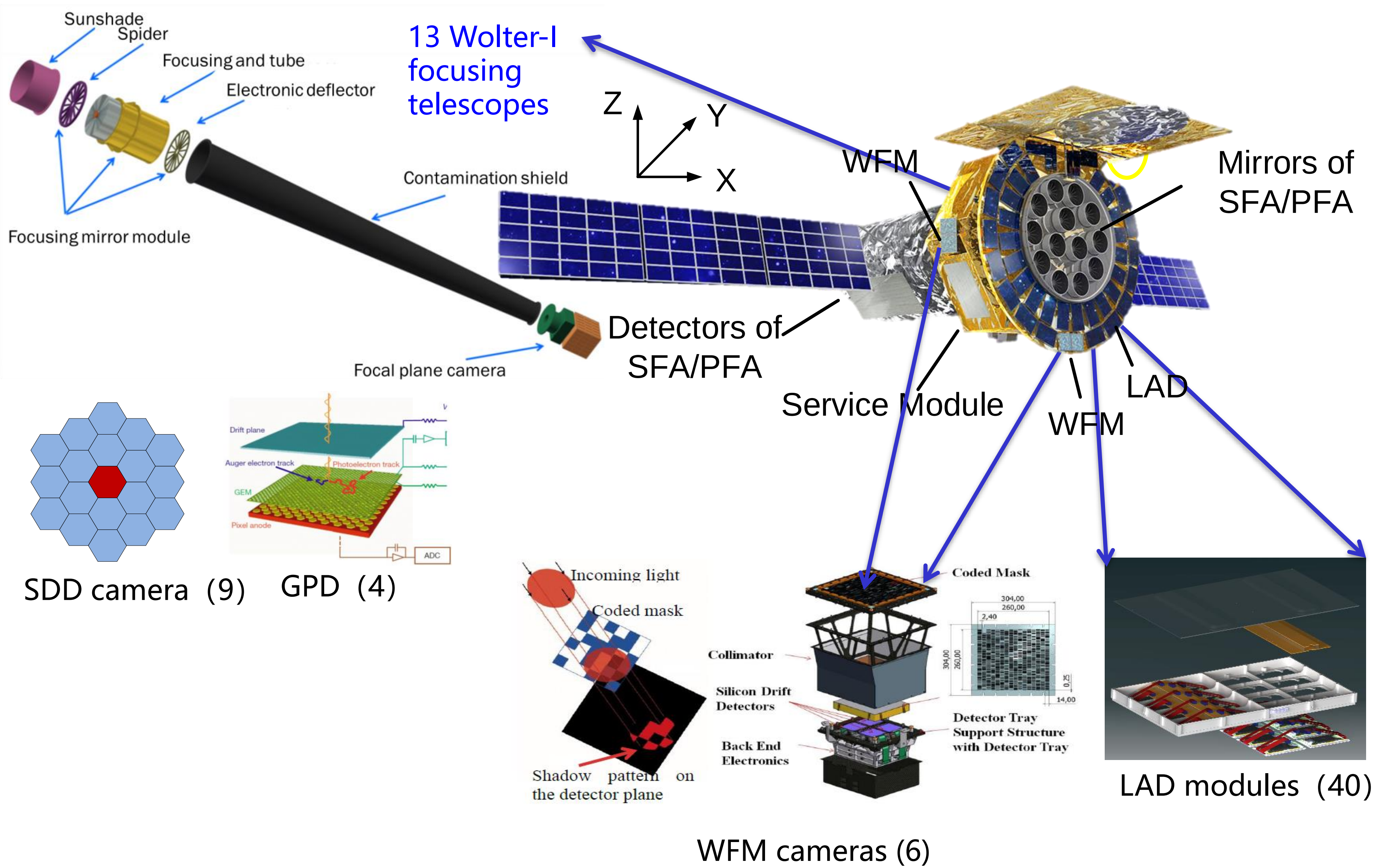
eXTP Mission Overview

Parameter	Value
Orbit	550 km, inclination ~ 0°
Pointing	3-axis stabilized, < 0.01° (3σ)
Launch	LM-5, @Wenchang (Hainan Island)
Launch mass	5300 kg
Telemetry	3.2 Tb/day (X-band or Ka-band)
Burst alert	BeiDou Navigation Satellite System; VHF transmitter (SVOM);
Ground Stations	Colombo (China), Malindi (Italy)
Mission duration	5 years (goal 8 years)
Launch date	~ 2029



Accommodation concept by MircoSat

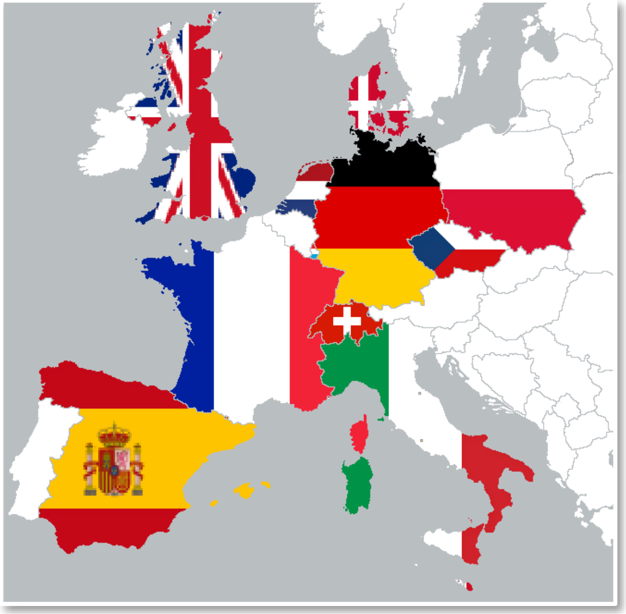
eXTP payload accommodation



International Partners in eXTP

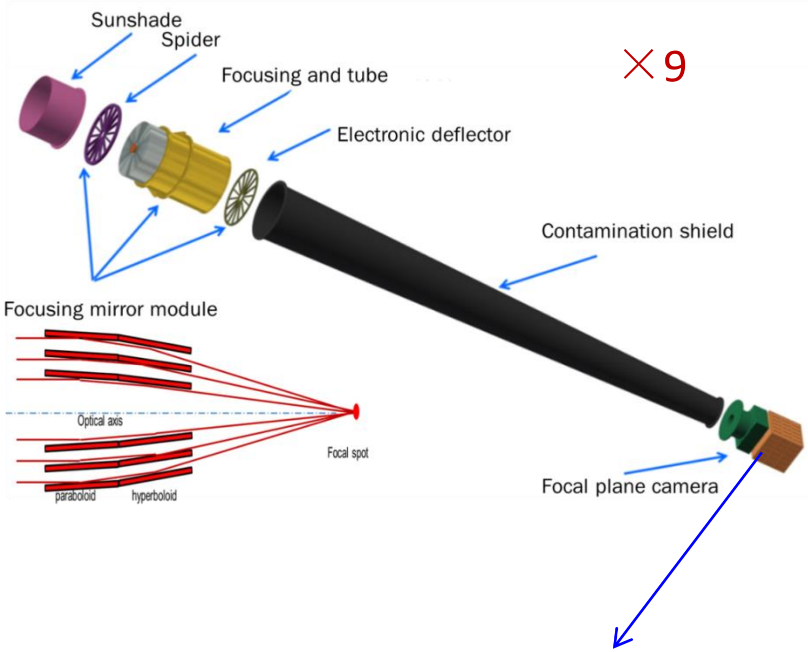
esa is considering eXTP MoO.

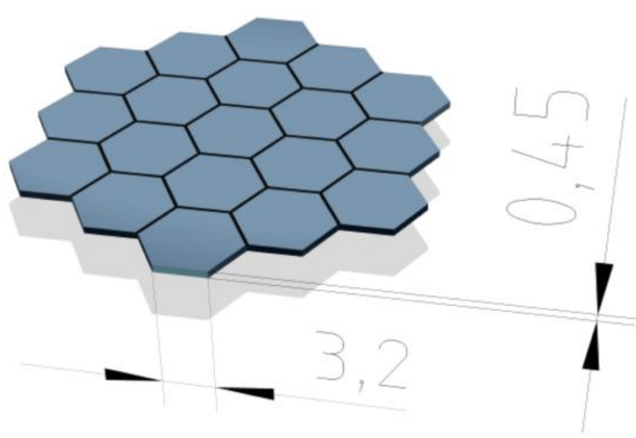
Nederlandse Onderzoekschool voor Astronomie



eXTP Scientific Payload:
SFA – Spectroscopy Focusing Array

- Large collecting area achieved by multiple optics with short focal length.
- 9 grazing incidence Wolter-I optics with 5.25m F.L., 45 shells/module , D=60cm
- Non-imaging, 1′ (HPD), 3′ (W90), 12′ FoV
- 19-cell SDD array: multi-pixel to enable background subtraction
- Energy range: 0.5-10 keV
- Energy resolution: ≤ 180 eV @ 6keV
- Time resolution: 10μs
- Absolute timing accuracy: 2μs
- Dead time: < 5% @ 1Crab
- Sensitivity: 3×10^{-12} erg/cm^2/s (3σ, 10 s)





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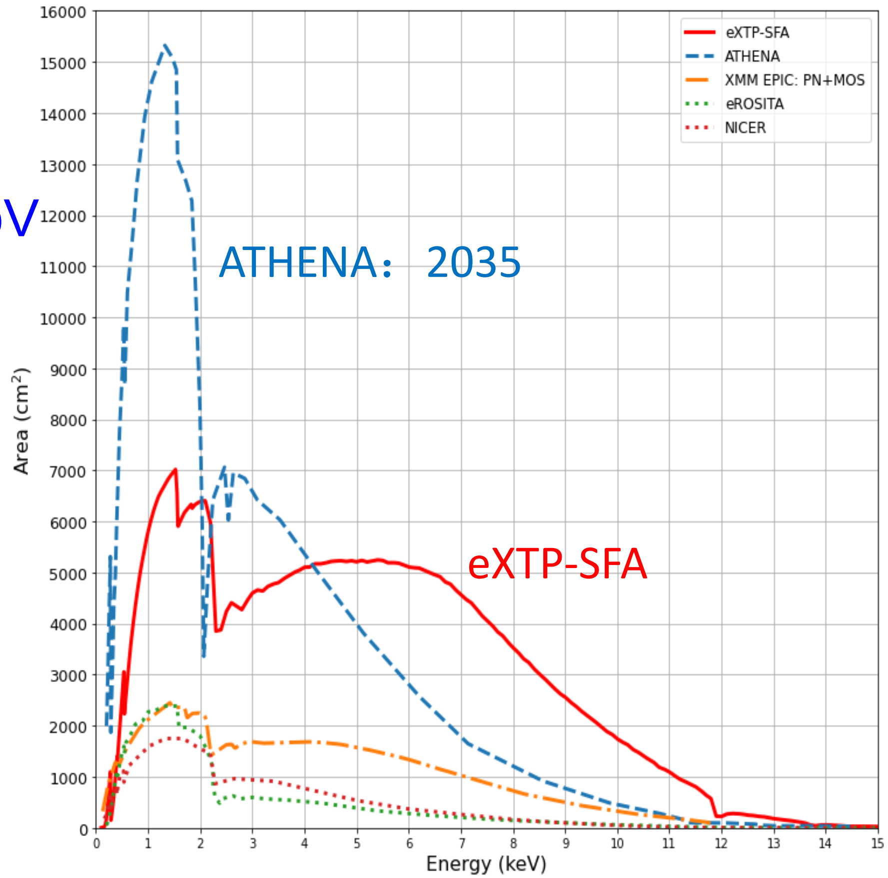
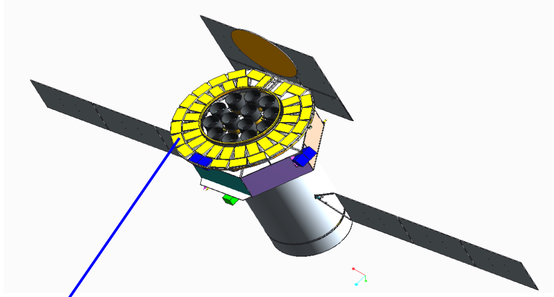
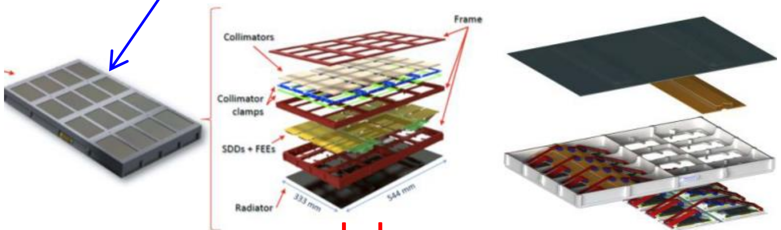


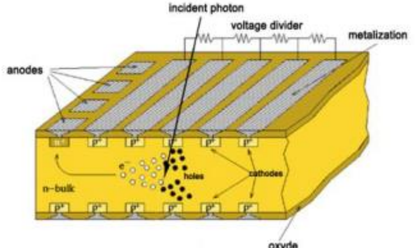
eXTP Scientific Payload: LAD – Large Area Detector

- Spectral and timing observation
- 40 modules
- Collimated, large area SDD detector
- Energy range: 2-30 keV (goal 50keV)
- Energy resolution: < 240eV @ 6keV
- Field of View: 1° (FWHM)
- Time resolution: 10μs
- Absolute time accuracy: 2μs
- Throughput: ≥ 1 Crab sustained
- Background: < 5mCrab
- Total effective area: 3.4m² @ 8keV

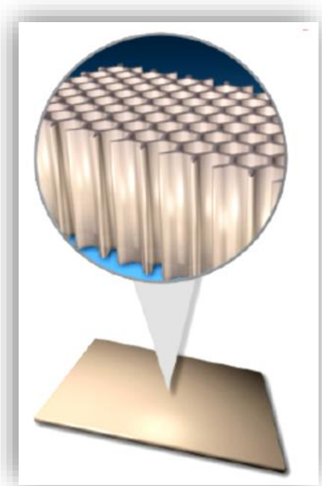




module



SDD: 2x112 anodes, pitch = 970μm



MCP collimator

Thermal/optical filter

eXTP Scientific Payload: LAD – Large Area Detector

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- 40 modules
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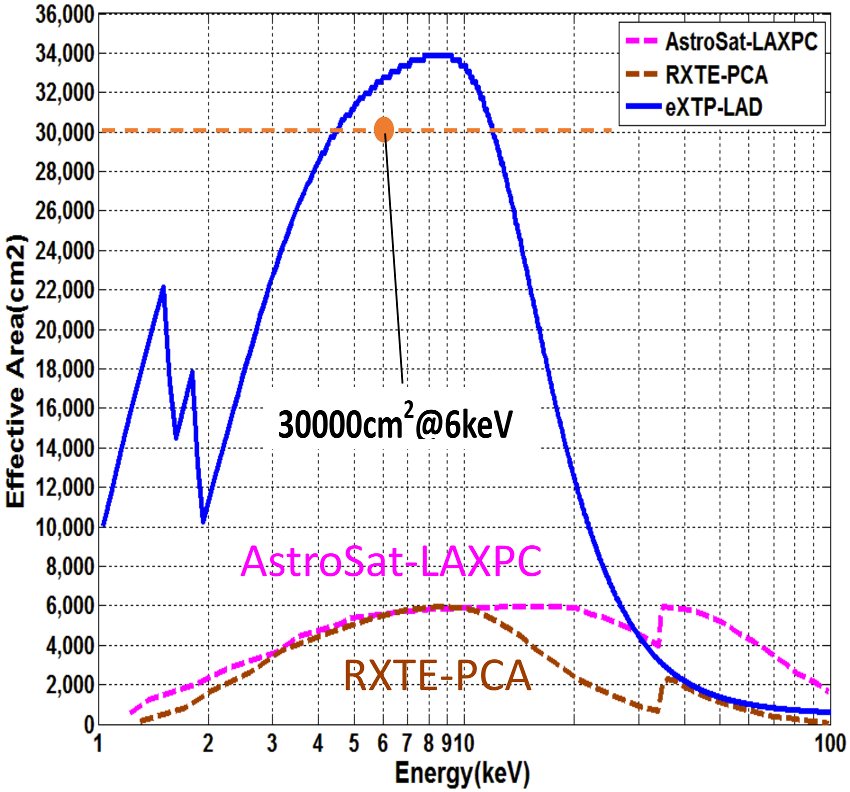
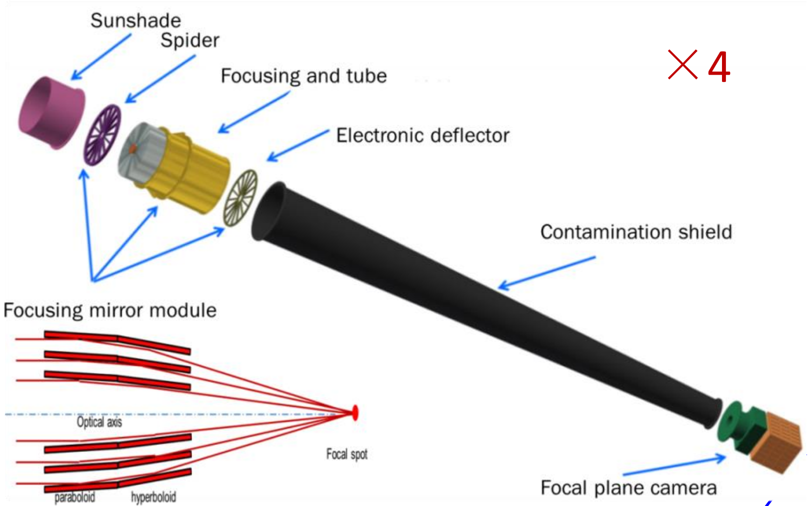
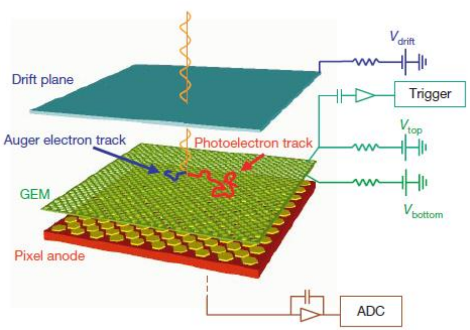


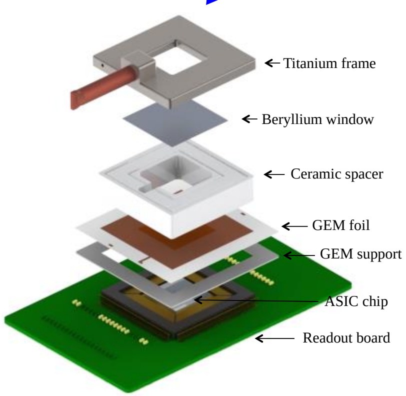
eXTP Scientific Payload:
PFA – Polarimetry Focusing Array

- Large collecting area achieved by multiple optics with short focal length.
- 4 grazing incidence Wolter-I optics with 5.25m F.L., 45 shells/module, D=60cm
- Imaging, resolution ≤ 30″(HPD, goal 15″)
- Field of view: 8′
- Gas Pixel Detector (GPD): photo-electron tracking
- Energy range: 2-8 keV
- Energy resolution: ≤ 1.8 keV @ 6keV
- Time resolution: 500μs
- Absolute timing accuracy: 2μs
- MDP: < 3% (10^6s, 1mCrab)





Designed by the INFN-Pisa group (Bellazzini et al.)



GPD prototype (Tsinghua)

eXTP Scientific Payload:
PFA – Polarimetry Focusing Array

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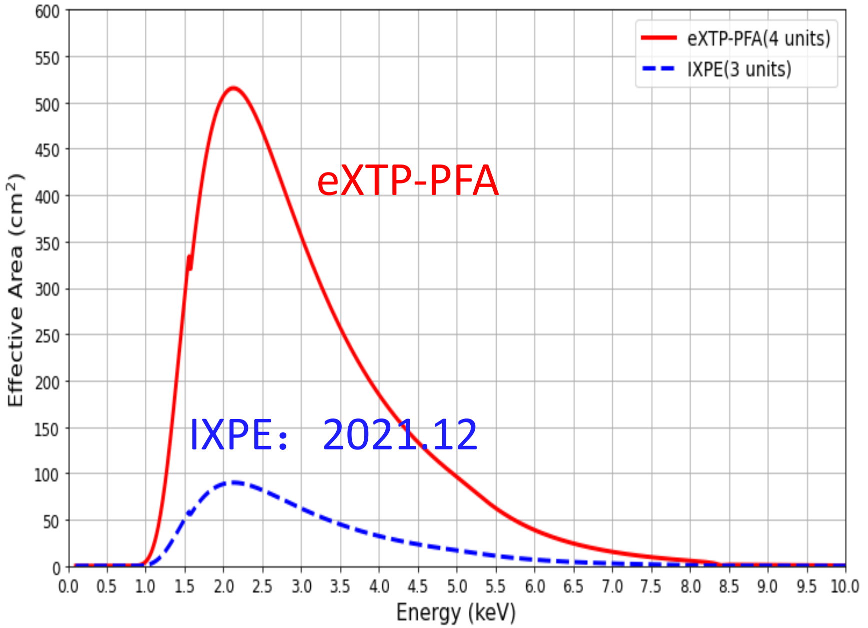
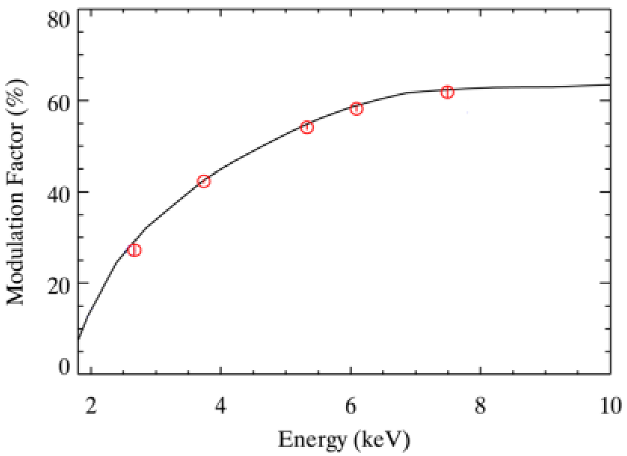
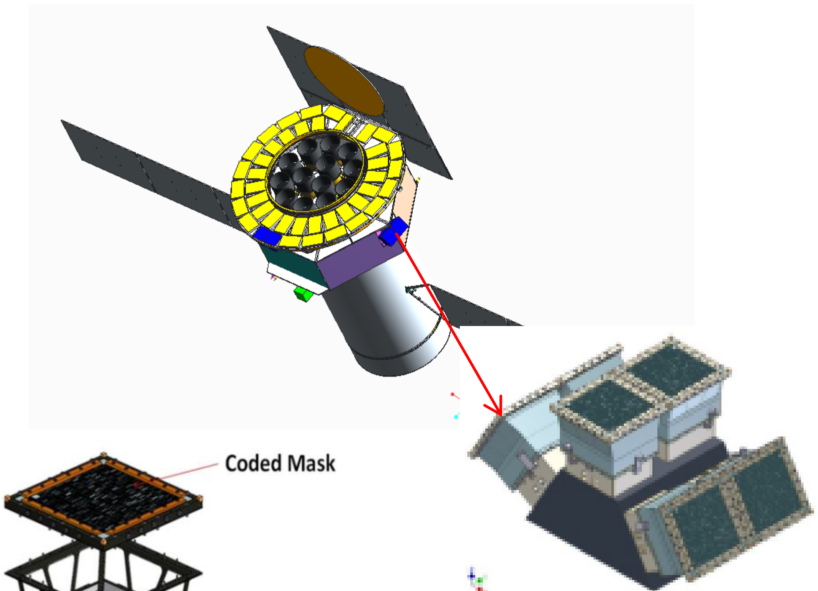
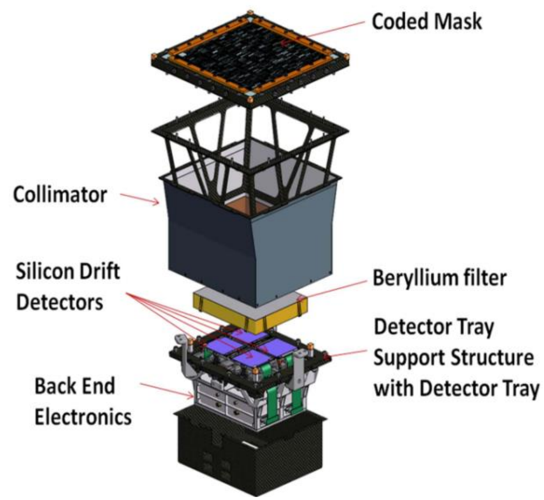




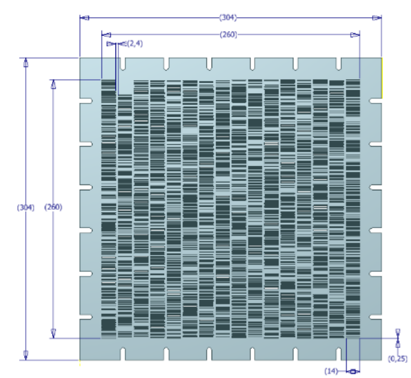
eXTP Scientific Payload: WFM – Wide Field Monitor

- 3 units (6 cameras)
- 2D Imaging, 5′ (FWHM) resolution
- Location accuracy: ≤ 1′
- Field of view: ≥ 3.2 Sr (at 20% response)
- Energy range: 2-50 keV
- Energy res.: ≤ 300eV @ 6keV
- Time resolution: 10μs
- Absolute time accuracy: 2μs
- Peak sensitivity (5σ): 1Crab (1s), 5mCrab (50ks)

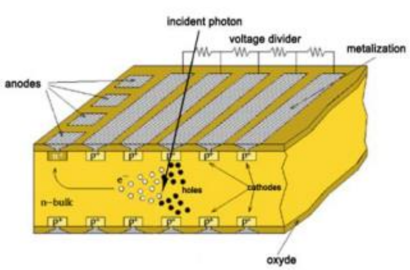




Camera module



1.5D coded mask



SDD: 2x384 anodes, pitch = 169μm

eXTP Scientific Payload: WFM – Wide Field Monitor

- 3 units (6 cameras)
- 2D Imaging, 5′ (FWHM) resolution
- Location accuracy: ≤ 1′
- Field of view: ≥ 3.2 Sr (at 20% response)
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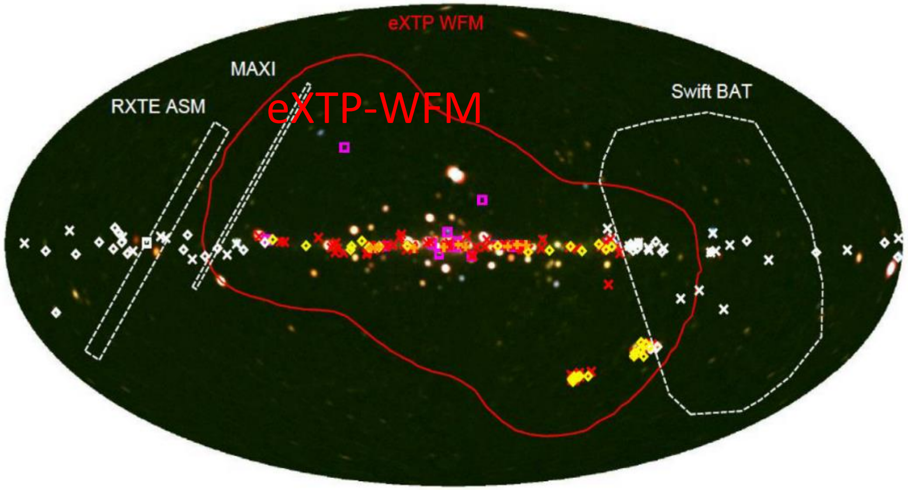
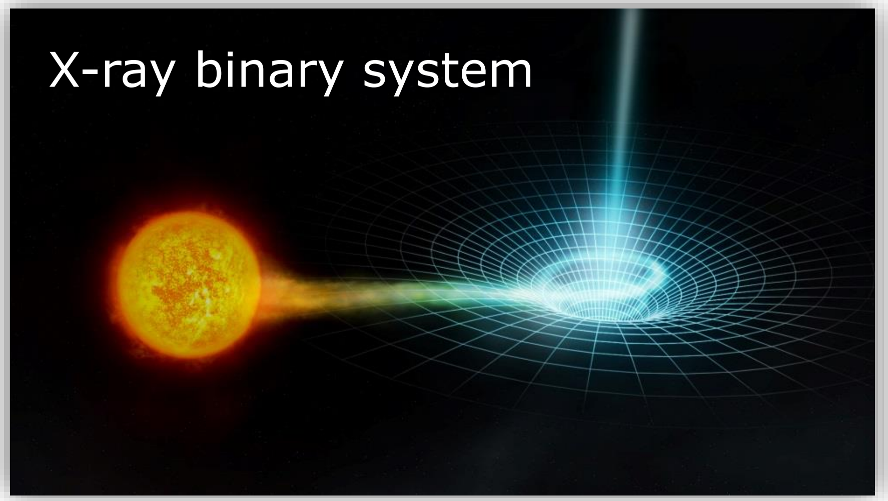
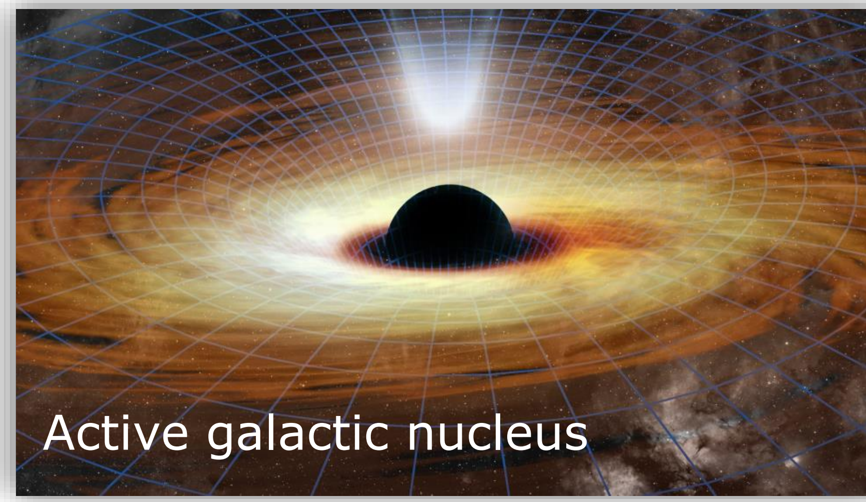


WFM field of View. (Background map courtesy of T. Mihara, RIKEN, JAXA, and the MAXI team)

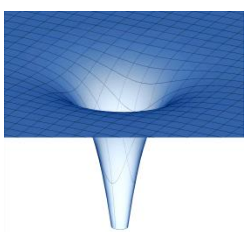
eXTP will also be a powerful observatory for time domain and multi-messenger astronomy!

Extreme Gravity

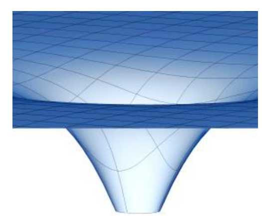




← eXTP covers wide mass range in uniform setting →



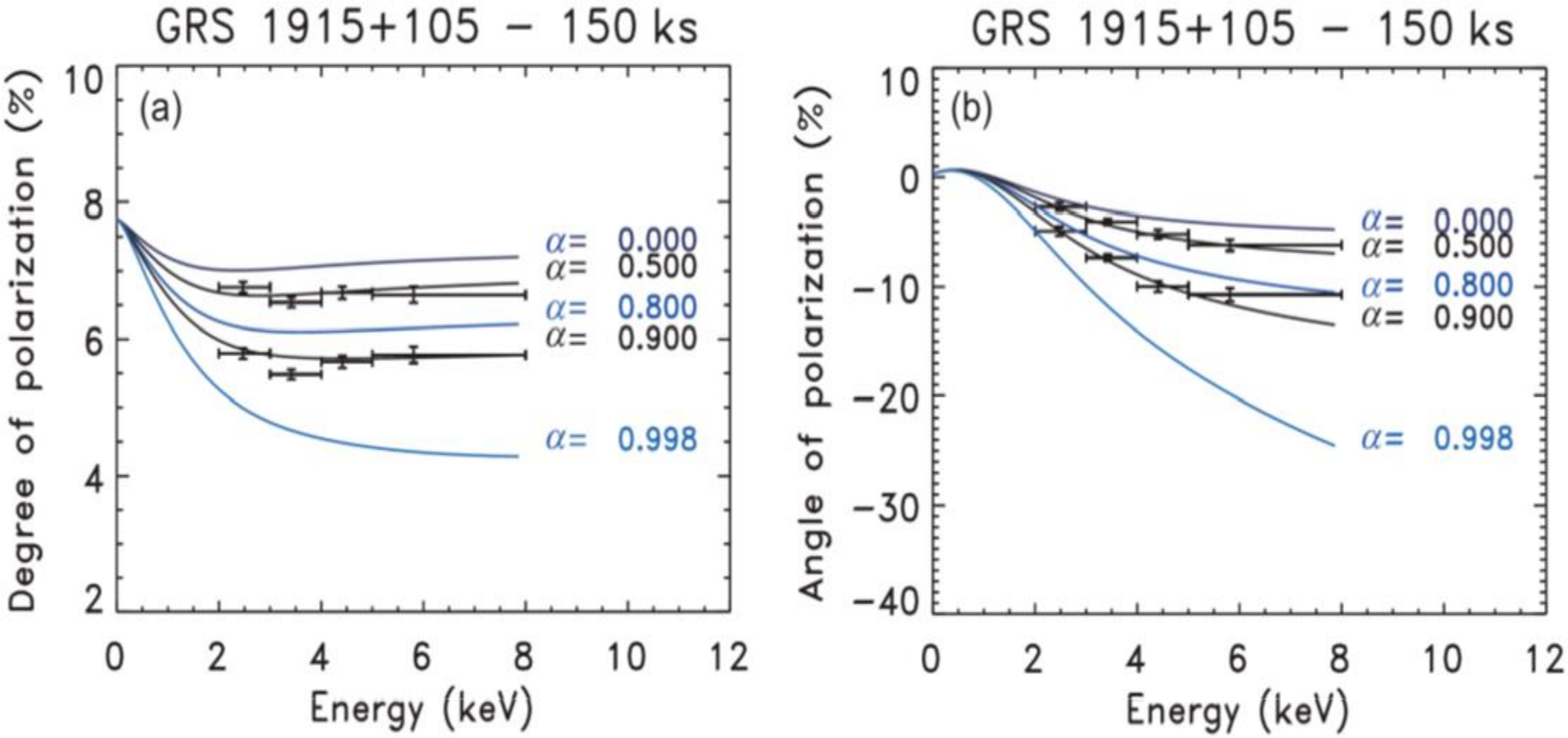
Stellar mass black hole
(or neutron star)
Strongly curved spacetime.
(10^{16} times Solar)



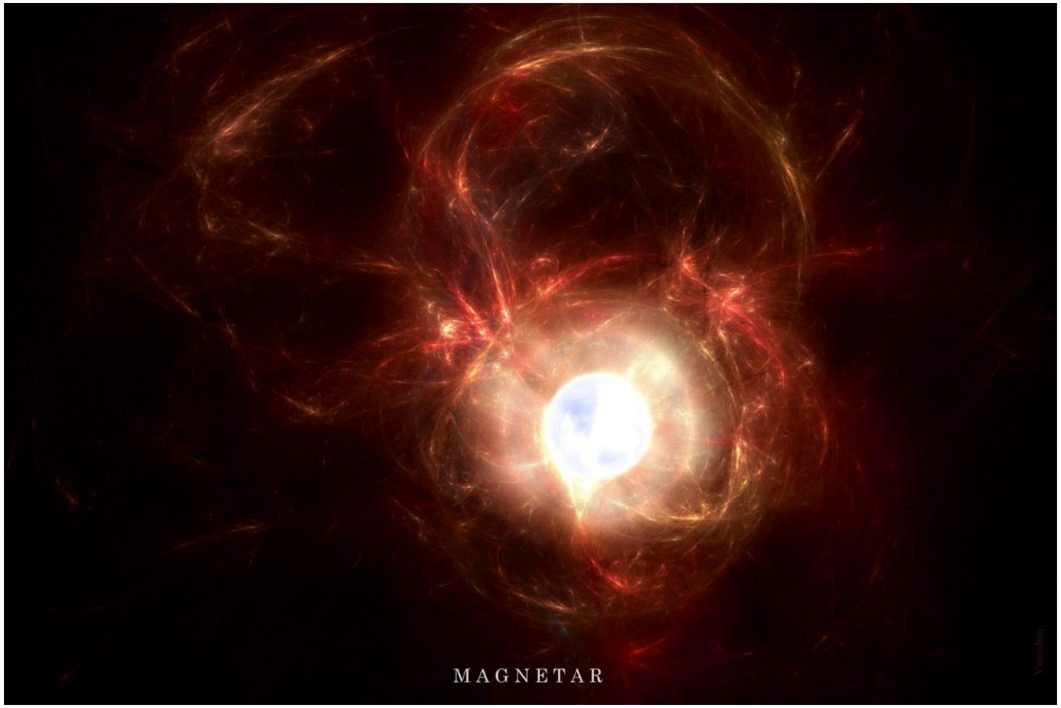
Supermassive black hole
Weakly curved spacetime
(~Solar)

Tests of GR predictions in the strong field regime of Gravity.
Complementary to gravitational wave experiments: eXTP probes stationary spacetime

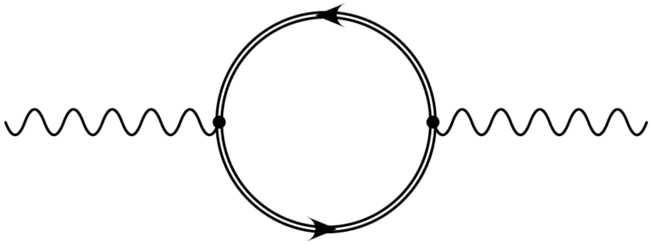
Measure BH spin with Polarimetry



Extreme Magnetism



Accreting Pulsars and *Magnetars hosts neutron stars with magnetic fields of* ***$10^{12\text{-}15}$ Gauss***
Strongest magnetic fields in lab. ***10^5 Gauss***



Test Quantum Electro-Dynamics effects → vacuum fluctuations: *is the propagation of light in vacuum modified by the magnetic field?*

$$\Delta n = \frac{\alpha}{4\pi}\frac{2}{15}\left(\frac{B}{4.4\times 10^{13}\ \mathrm{G}}\right)^2$$

Polarization in X-ray Pulsar: NS radius?

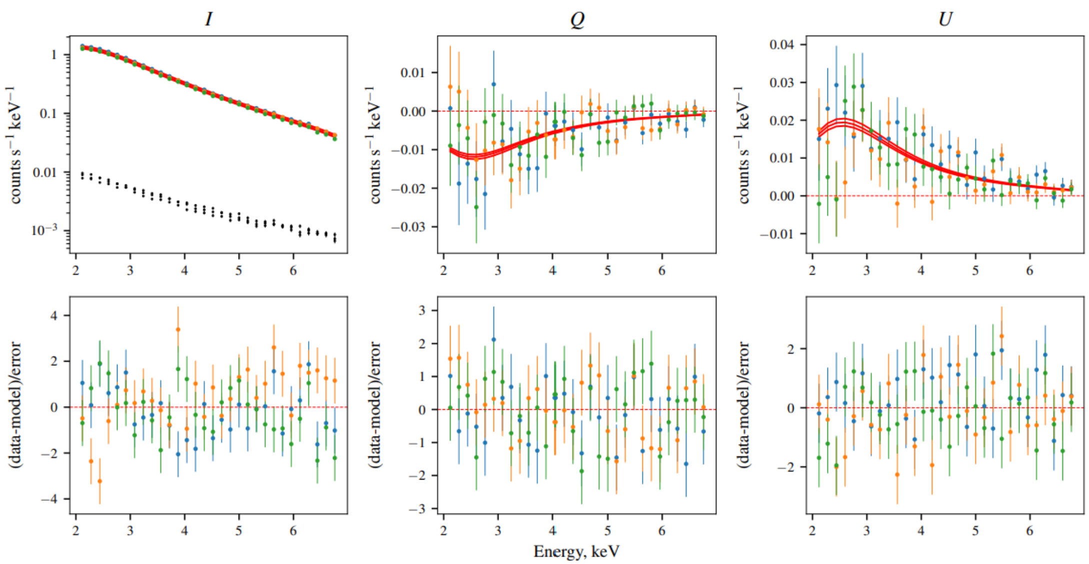
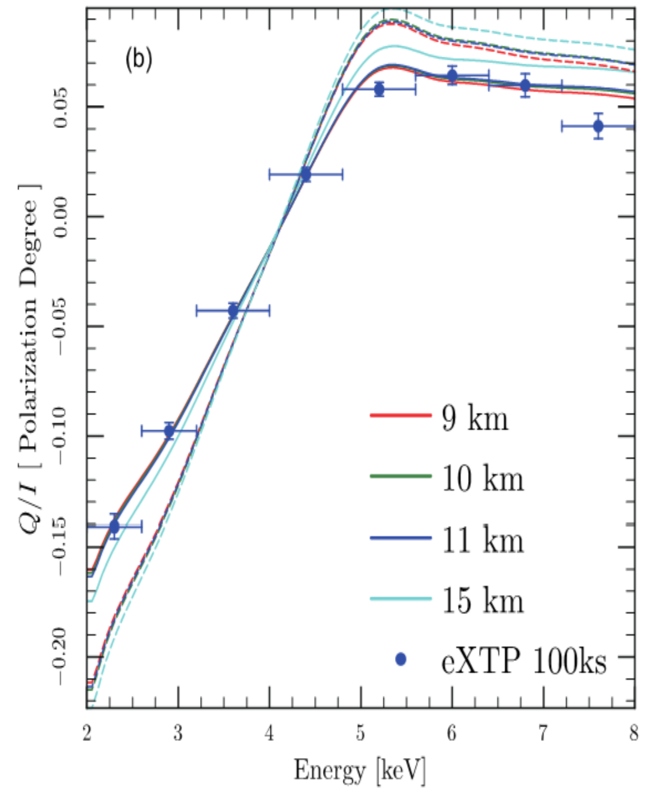


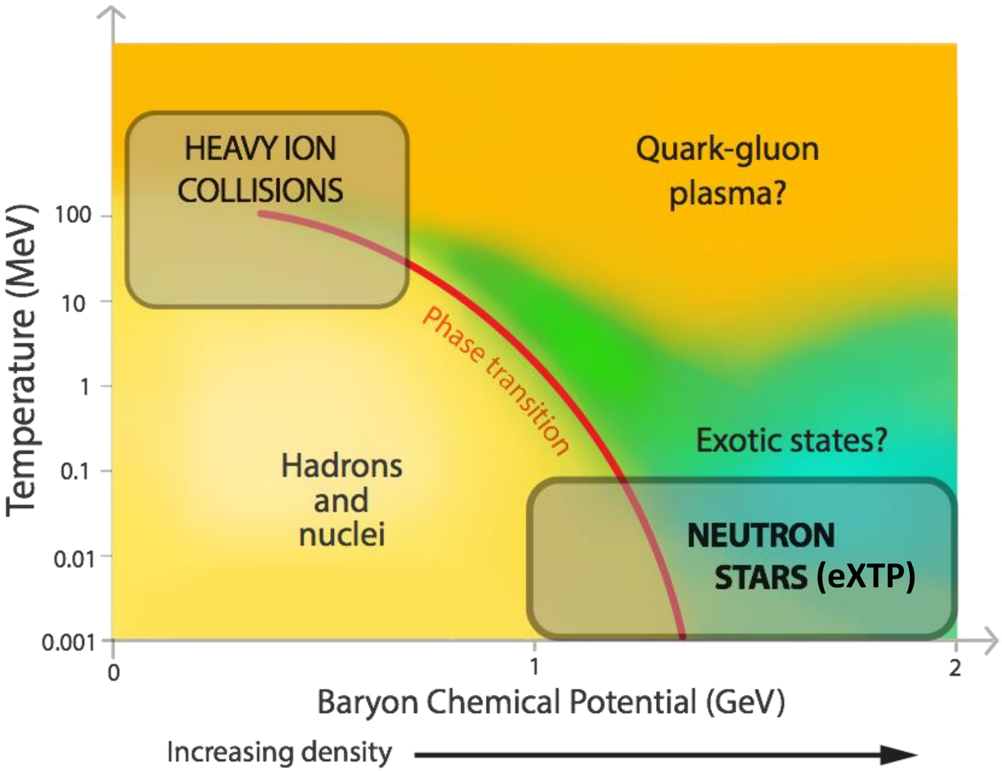
Figure S1: **Observed Stokes spectra of Her X-1.** The top row shows spectra of the three Stokes parameters I, Q, and U, while the bottom row shows the residuals to the best-fit model (`nthcomp` for intensity and `polconst` for Q and U). The results for the three detector units are color-coded, the black points in the first panel show the estimated background level for each detector.

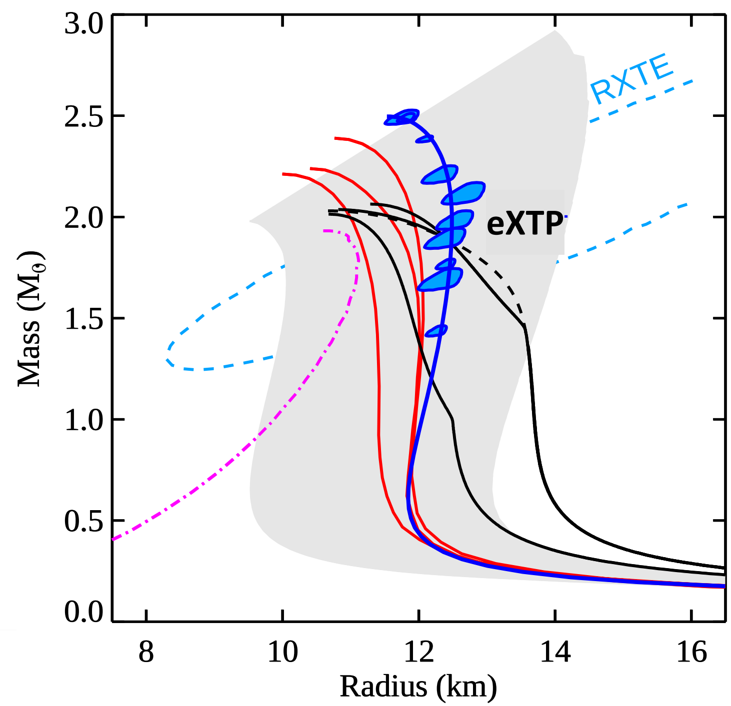


Doroshenko+ (IXPE), arXiv:2206.07138

X-ray pulsar HerX-1: 10^{12} G

Extreme Density: Neutron Stars EoS

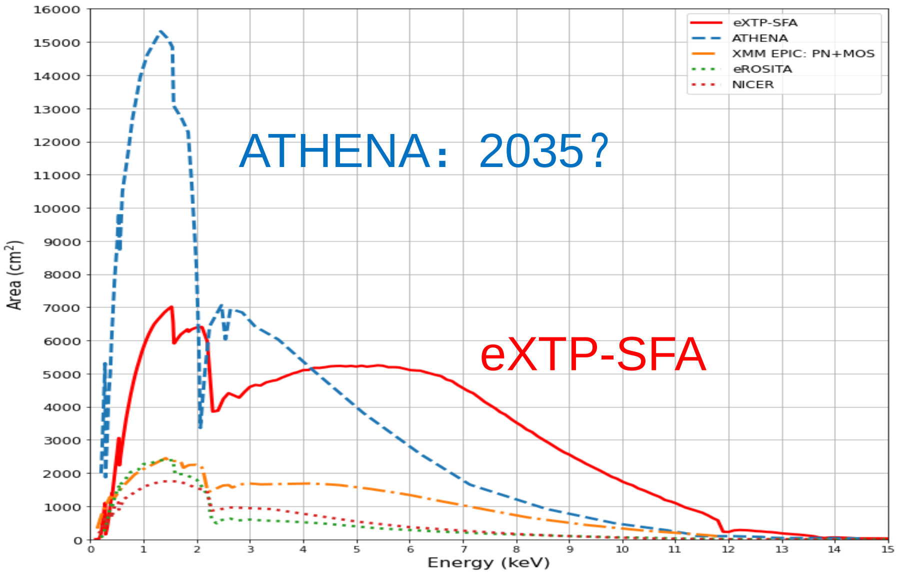


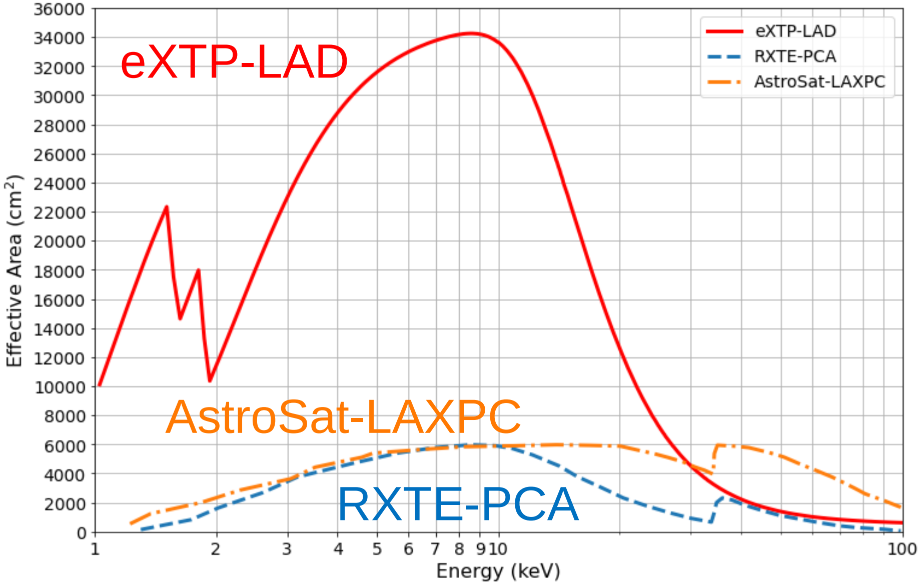


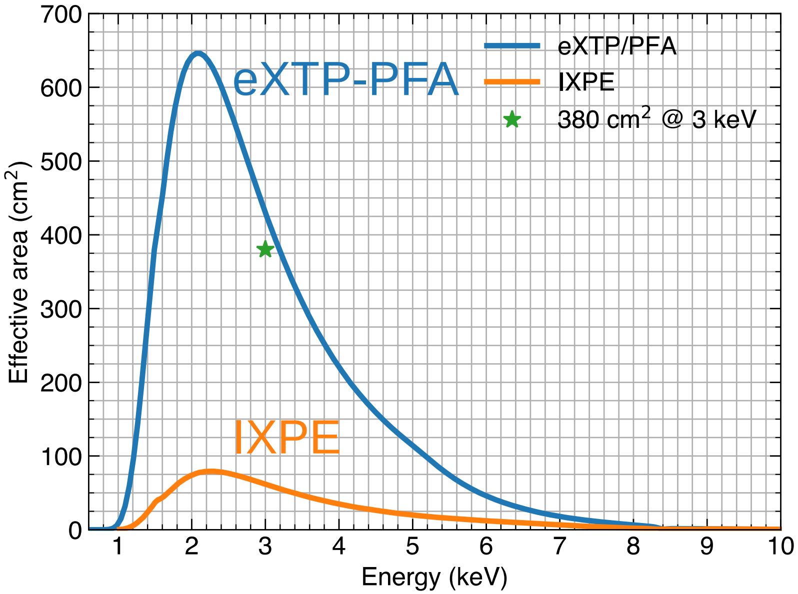
eXTP WILL STUDY **NUCLEONIC MATTER IN A UNIQUE REGIME**, AND **EXOTIC STATES OF MATTER (E.G., QUARK STARS)** THAT COULD NEVER EXIST IN THE LABORATORY.

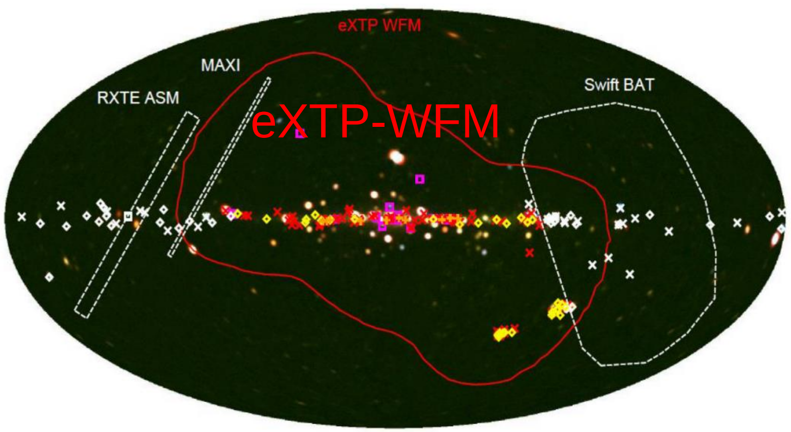
USING ONLY KNOWN SOURCES, PULSE PROFILE MODELLING MEASUREMENTS WILL **MAP THE M-R RELATION** AND HENCE THE **EQUATION OF STATE (EOS)**.

Main performance: eff. area & field of view

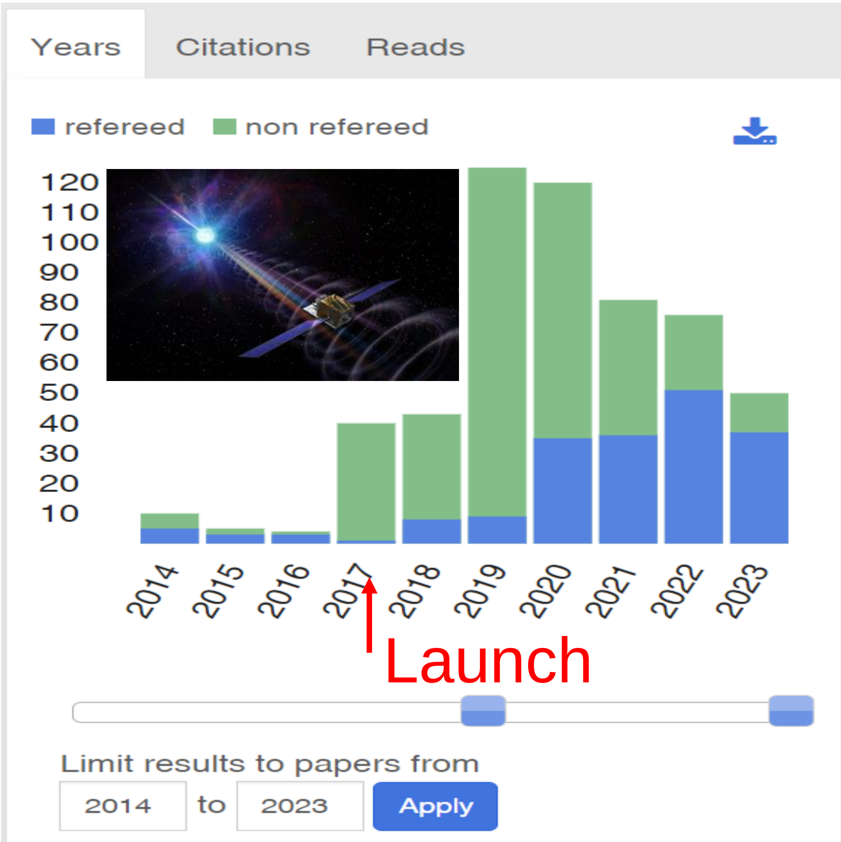




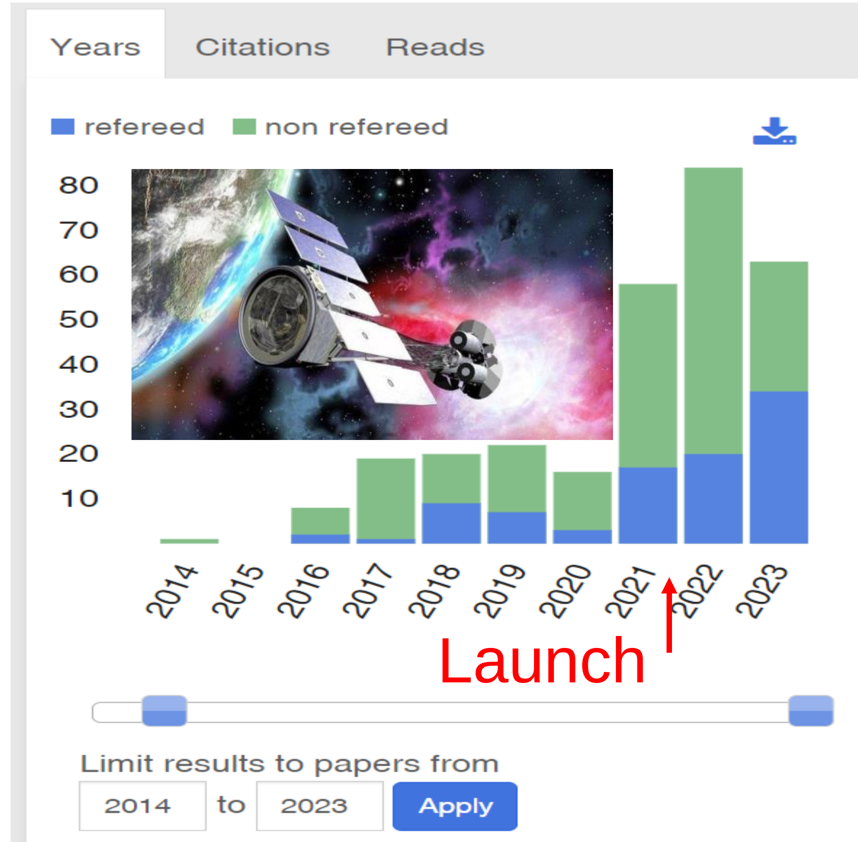




Publications: HXMT vs IXPE



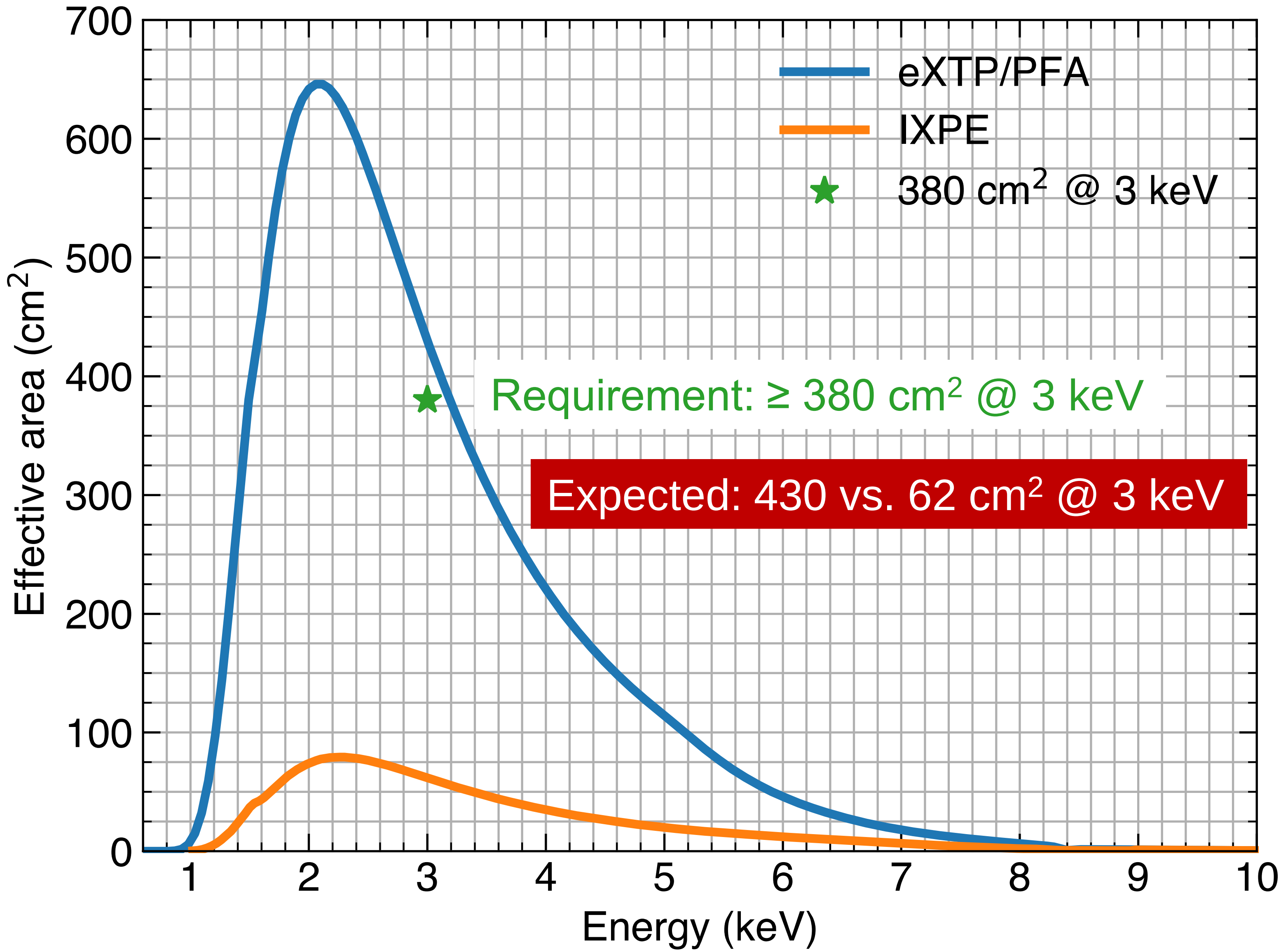
HXMT: China's 1st X-ray satellite



IXPE: 1st X-ray polarimetry satellite

Beyond HXMT + IXPE?

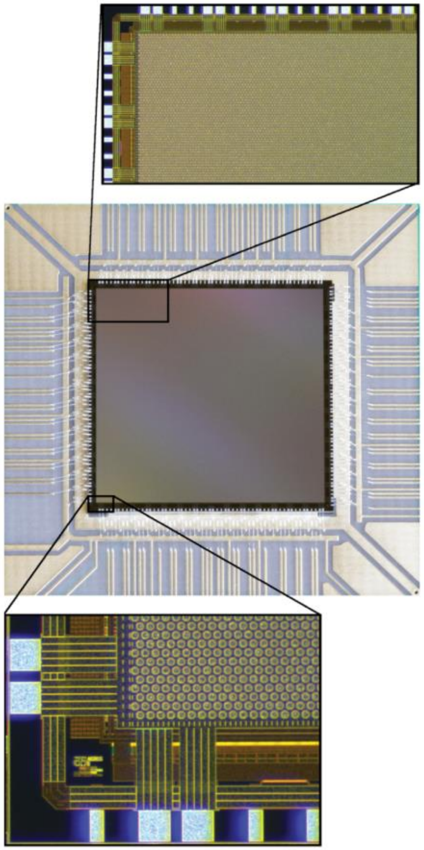
From IXPE to eXTP



A new ASIC will be used

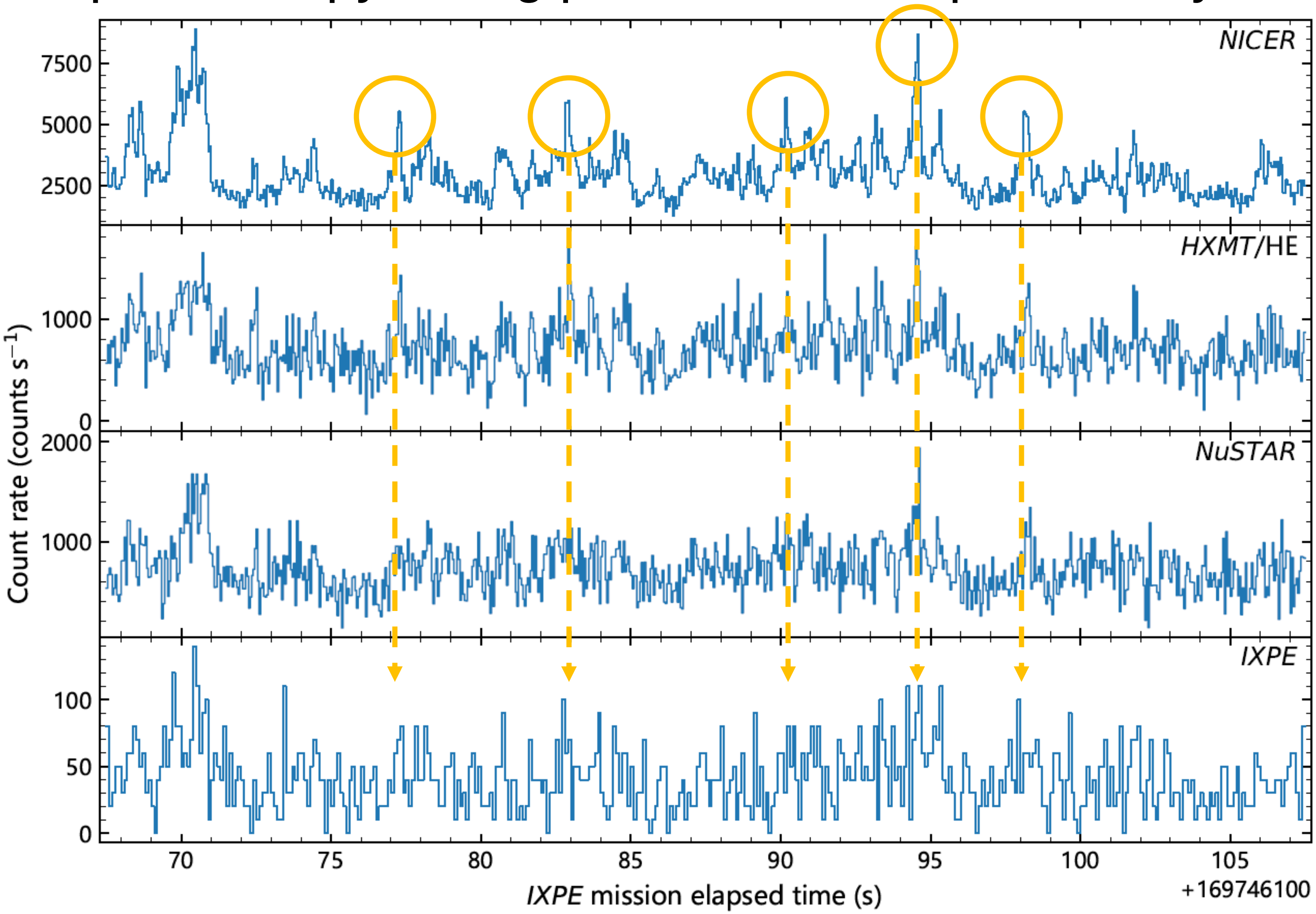
Parameters	XPOL-III	XPOL-I
Number of pixels	304 × 352	300 × 352
Physical pitch	50 μm	50 μm
Shaping time	1 μs	3-10 μs (adjustable)
Pixel gain	200 mV fC^{-1}	400 mV fC^{-1}
Pixel noise	30 *e*- ENC	50 *e*- ENC
Full scale linear range	30k *e*-	30k *e*-
Trigger coupling mode	AC	DC
Minimum trigger threshold	~150 *e*-	
Dead time	~150 μs	~1 ms
Maximum count rate	~6k * 4 c s^{-1}	~0.9k * 3 c s^{-1}

9× higher (to compensate the larger effective area)



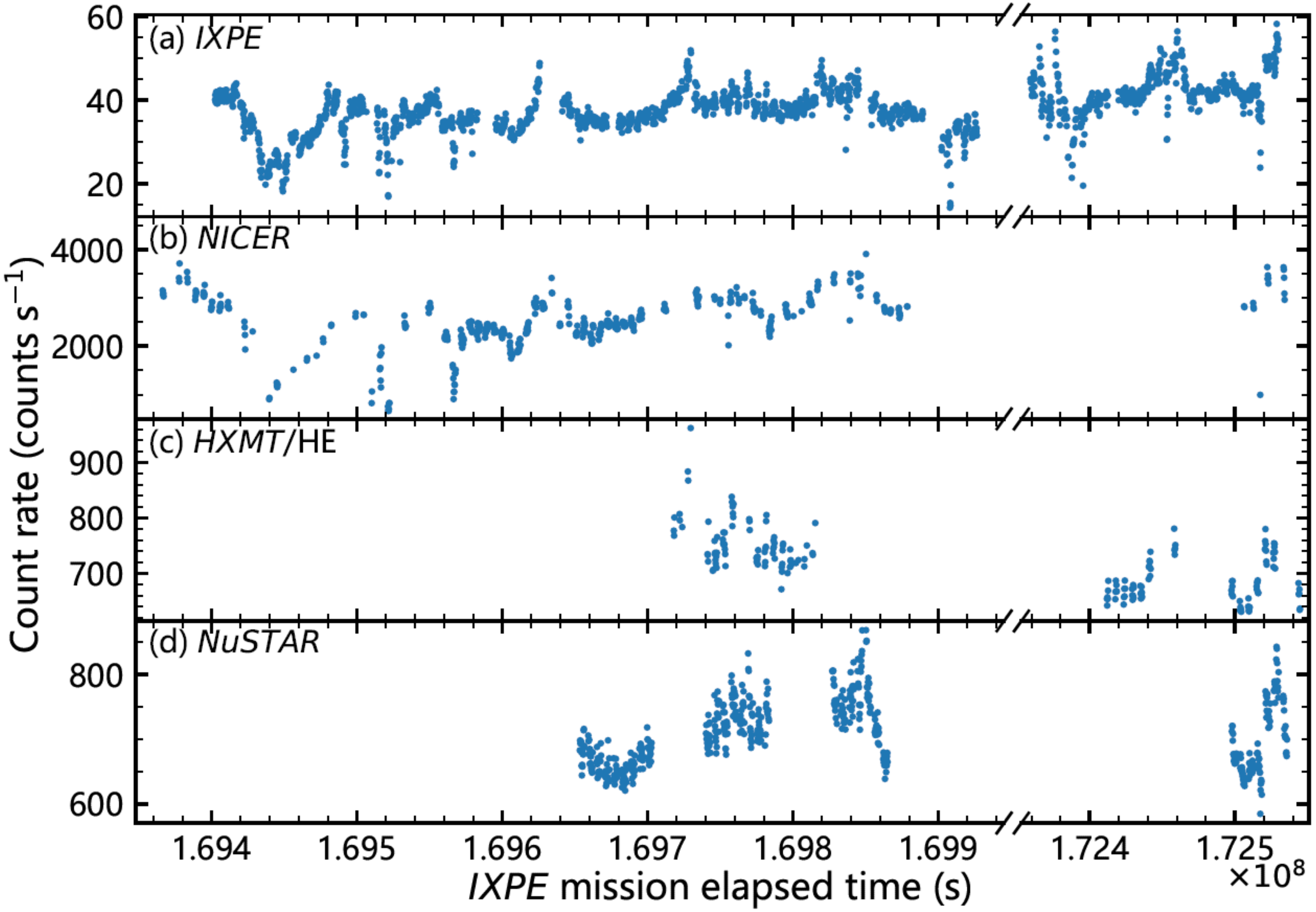
(Minuti et. al 2023)

Simultaneous observations are needed for spectroscopy/timing/phase-resolved polarimetry



Example: to compare the X-ray polarimetry during flares and quiescence. Most of the flares that can be identified with NICER and HXMT cannot be seen in the IXPE light curve.

Really simultaneous? Difficult for LEO satellites



Overlapped time fraction

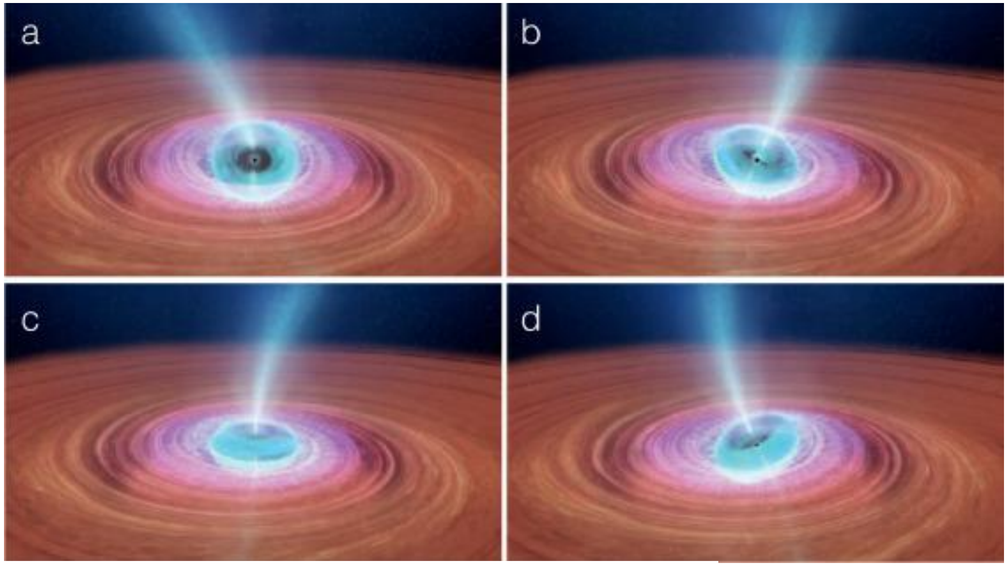
12%

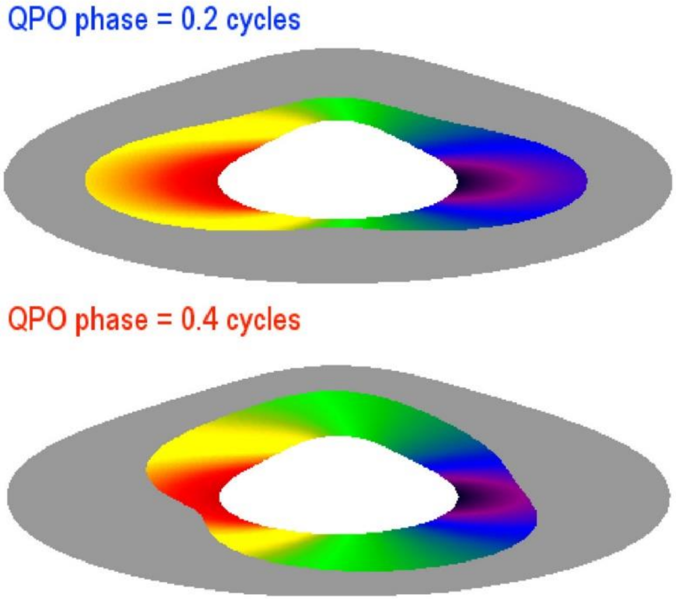
8%

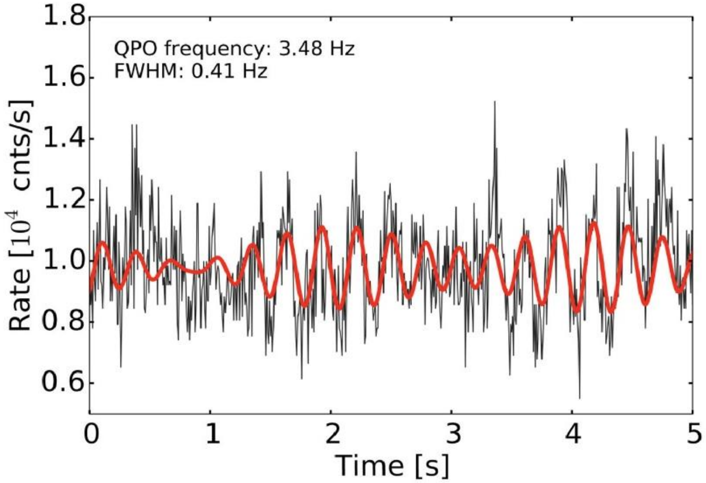
14%

Not only a larger version of IXPE

Example: timing-polarimetry







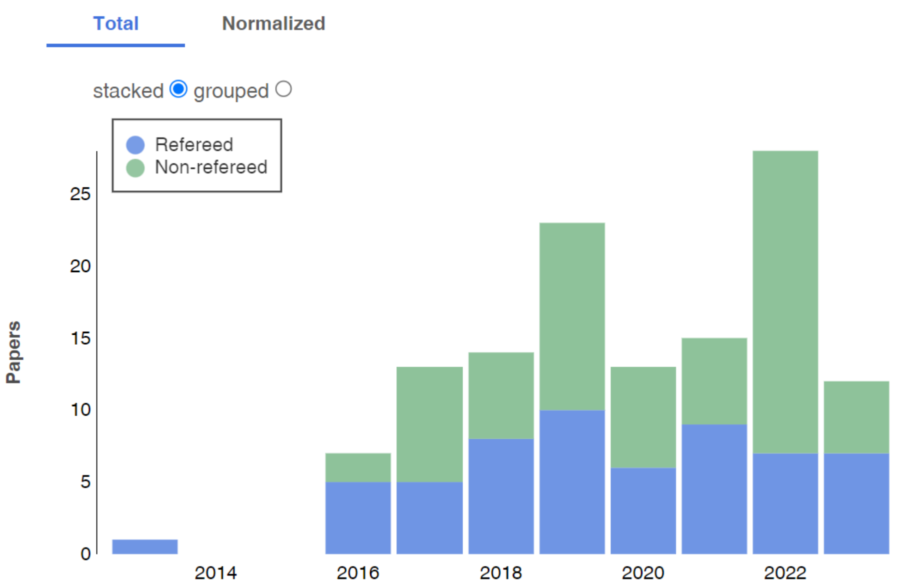
Need LAD/SFA to fold the QPOs

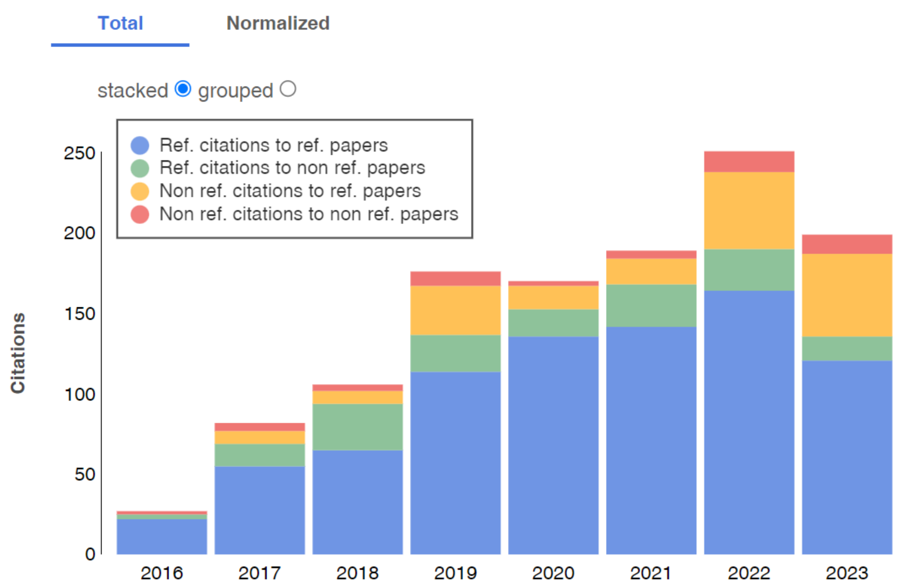
Ingram et al. 2017
Ingram & Maccarone 2017
Ingram & Motta 2019

IXPE + X vs. eXTP

- IXPE + X
  - Difficult to re-schedule multiple missions
  - Low flexibility in response to transient sources
  - Earth occultation: joint observations are not really simultaneous
- eXTP
  - All instruments point to the same target
  - *Bona fide* simultaneous
  - Almost no telemetry limit for bright sources
- IXPE + X cannot fulfill the job
  - if the source has variability on orbital timescale (~90 min)
  - if one tries to study short-term variability (Δt < ~90 min)
- For the same source, eXTP allows for
  - polarimetry at a better timing/energy/phase resolution (~7 times better)
- eXTP is more than a larger IXPE

eXTP publications and their citations





NASA ADS: abs:"eXTP“ on 2023.08.29

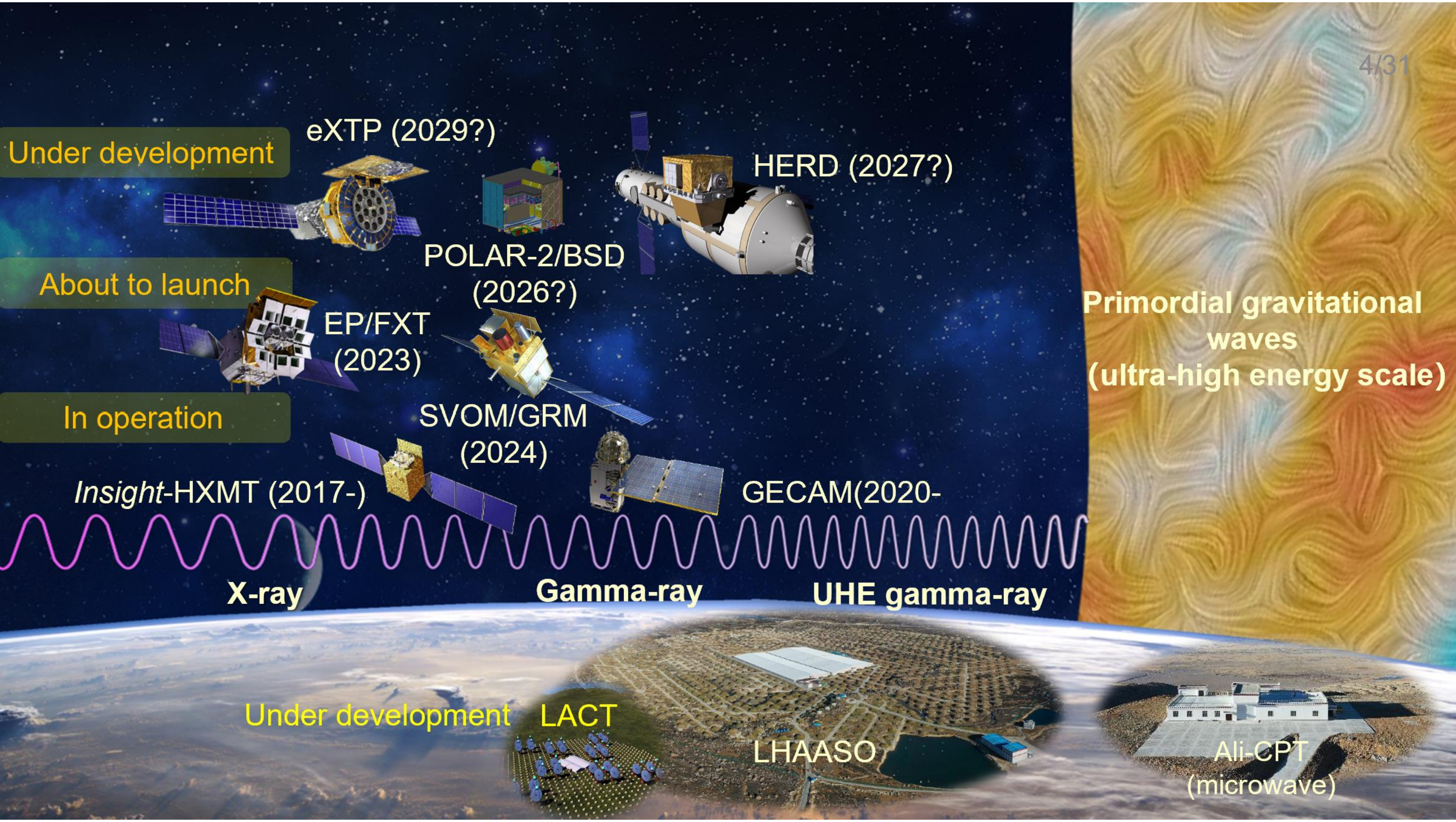
The community is looking forward to eXTP in orbit!

China is active in space high energy astronomy

- DAMPE, POLAR, Insight-HXMT, GECAM, EP pathfinder launched in 2015/16/17/20/22
  - Insight-HXMT is very flexible in ToOs and monitoring bright transients with high cadence and long observations; GECAM as ASM has good low energy response & near real-time alert capability
- SVOM, EP, POLAR-2 to be launched in ~2023-2025
  - Large FoV & deep high energy monitoring, with quick & deep X-ray/optical follow-up capabilities; GRB polarimetry.
- Two large future missions：flagship-class
  - HERD: To provide sensitive gamma-ray (GeV to TeV) sky monitoring, on China's Space Station, 2027?
  - eXTP: To provide X-ray spectral-timing-polarimetry with powerful WFMs, space X-ray observatory, 2029?

Welcome to join HERD & eXTP!

The fleet of facilities of our division in IHEP



Welcome to join us in IHEP! Thanks!