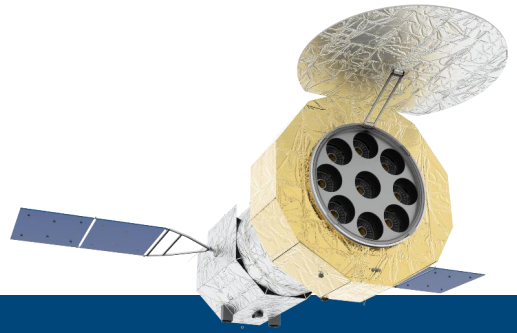


High Energy Astrophysics and Cosmology in the Era of All-sky Surveys
June 15 – 19, 2026, Yerevan, Armenia

Exploring the Extremes with eXTP

Hua Feng

2026.06.16

粒子天体物理全国重点实验室
State Key Laboratory of Particle Astrophysics

中国科学院高能物理研究所
Institute of High Energy Physics, Chinese Academy of Sciences

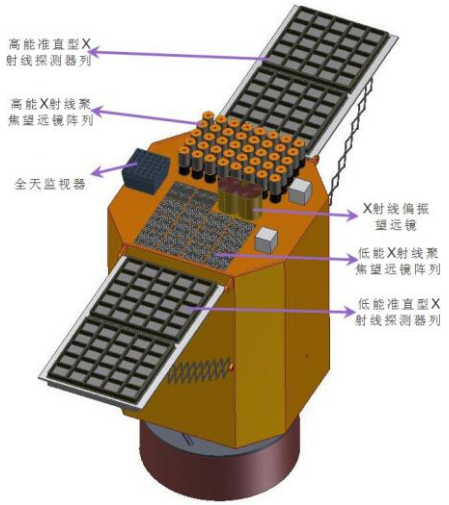
Outline

History and future

- **XTP mission concept proposed in 2007**
- **Phase 0: 2009-2011 (preliminary study)**
- **Phase A: 2011-2015 (background study)**
- **eXTP mission concept formed in 2014-2016 (S. N. Zhang et al. 2016, SPIE)**
  - eXTP = XTP + LOFT
  - The eXTP international consortium established in 2016
- **eXTP white papers published (Zhang et al. 2019, SCPMA)**
- **Phase B: Jan 2019 - Dec 2022 (advanced background study)**
  - Technology development, prototype/enginering model
  - Production/integration/test facility construction/upgrade
  - Internal Interface Review
  - Conceptual Design Review (SFA, PFA, S/C)
  - Instrument System Requirements Review (LAD & WFM, 2023.02)
- **Mission selected by CAS in 2024 and adopted in 2025**
- **Preliminary Design Review in November 2025 and then started Phase C**
- **Expected launch in 2030**

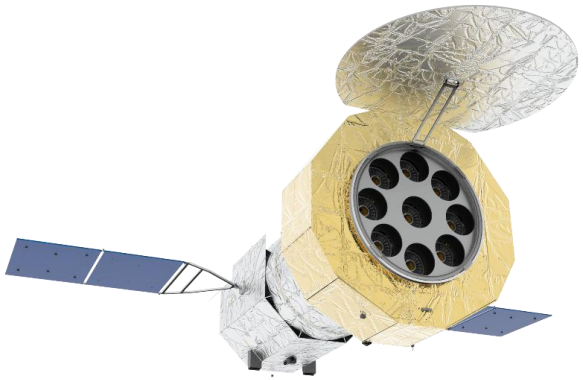
Evolution of the design

China: SFA + PFA
Europe: LAD +WFM



XTP
2007-2008

eXTP
2014-2023



eXTP at adoption
Since 2024

LOFT

PART 02

Mission Profile

Scientific requirements

Understanding physics under extreme gravity, density and magnetism

⇩

High throughput X-ray spectroscopy, timing and polarimetry

⇩

Spectroscopy Focusing Array (SFA)

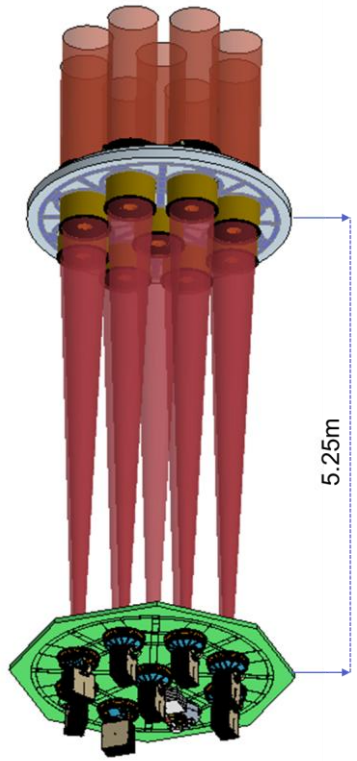
- Total effective area ≥ 3300 cm^2 @ 1.5 keV， ≥ 2000 cm^2@ 6 keV
- Energy range: 0.5-10 keV, resolution ≤ 180 eV@6 keV
- 5*SFA-T sensitivity ≤ $4*10^{-15}$ erg/s/cm^2 (0.5-10 keV, 5σ, 10^6s)
- SFA-I sensitivity ≤ $4.5*10^{-15}$ erg/s/cm^2 (0.5-10 keV, 5σ, 10^6s)

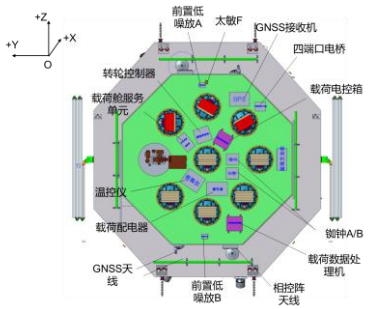
Polarimetry Focusing Array (PFA)

- Effective area ≥ 180 cm^2@3 keV
- Energy range 2-8 keV， resolution ≤ 1.8 keV@ 6 keV
- Minimum detectable polarization ≤ 3% (1mCrab, 10^6s)

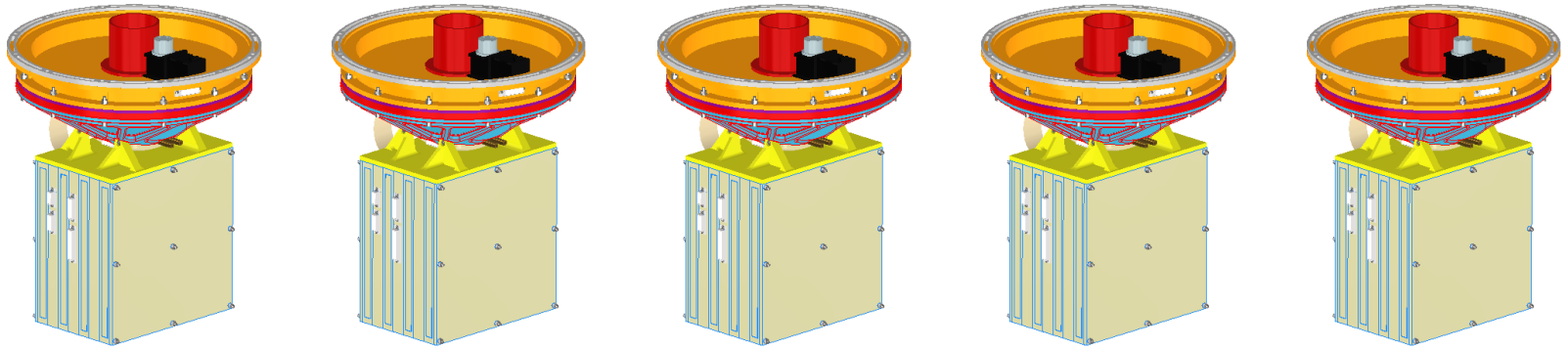
Super (NICER/XMM + IXPE)

Payload configuration

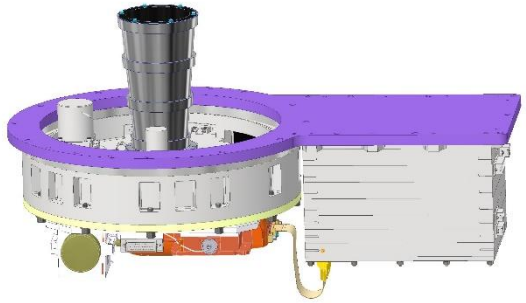




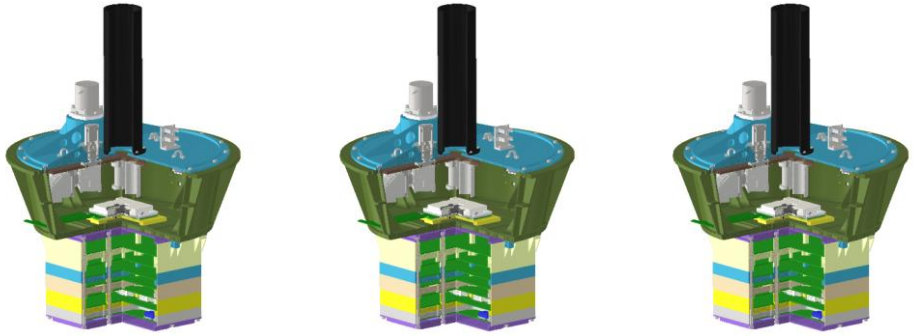
- Spectroscopy Focusing Array for Timing (SFA-T) × 5



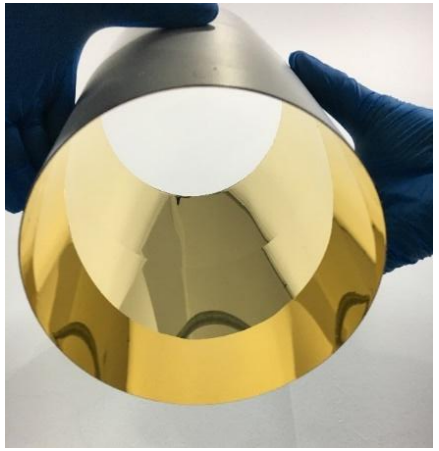
- Spectroscopy Focusing Array for Imaging (SFA-I) × 1

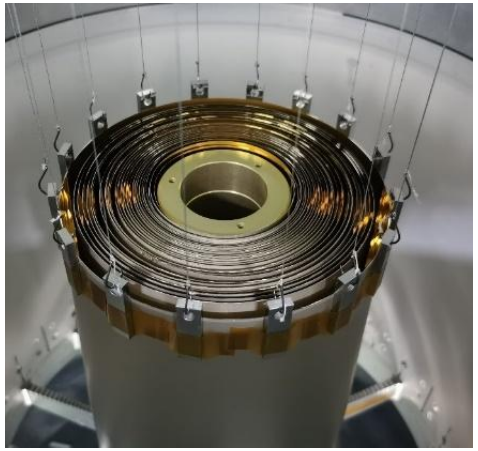


- Polarimetry Focusing Array (PFA) × 3

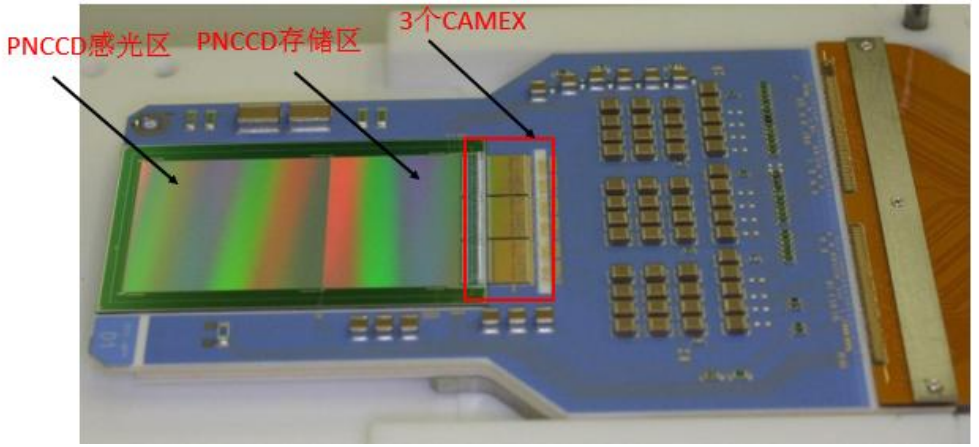


Mirrors and focal plane detectors

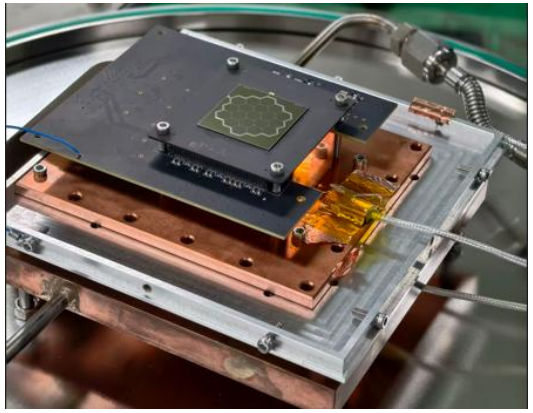


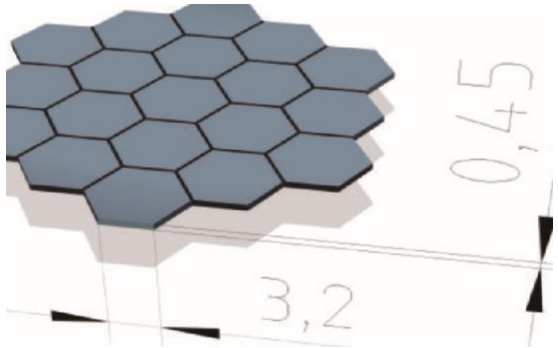


- Wolter-I focusing mirror assemblies × 9

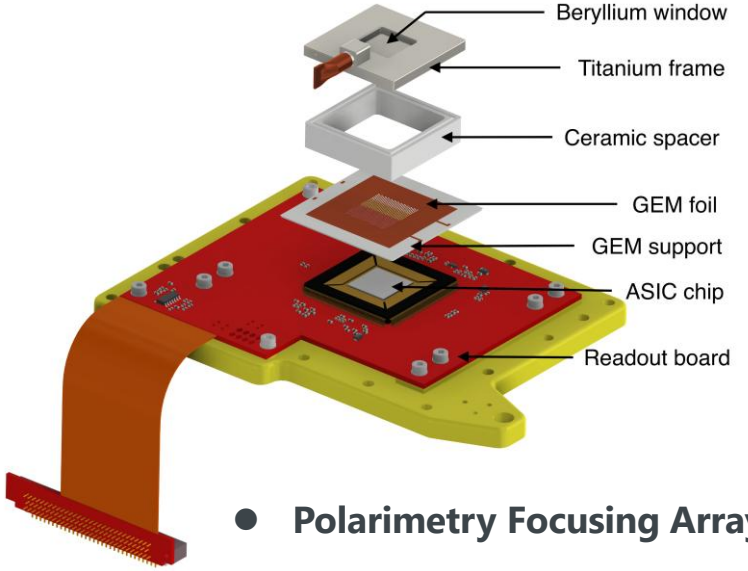


- Spectroscopy Focusing Array for Imaging (SFA-I) × 1



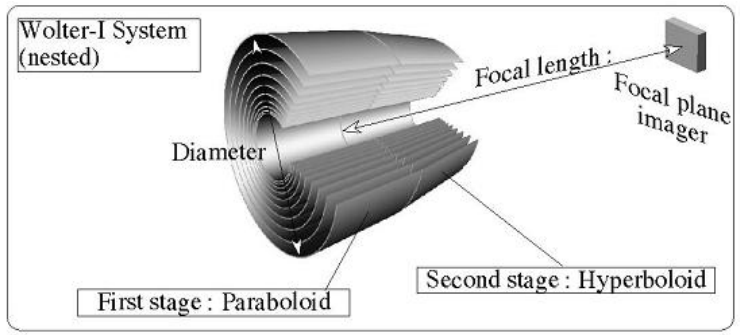


- Spectroscopy Focusing Array for Timing (SFA-T) × 5

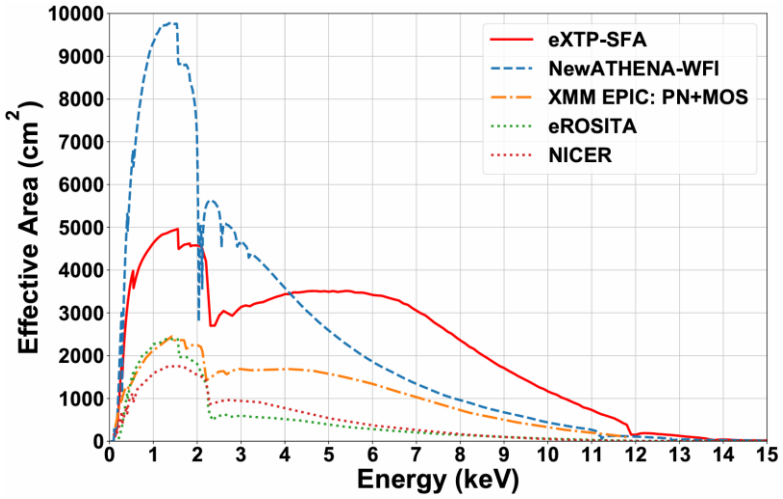


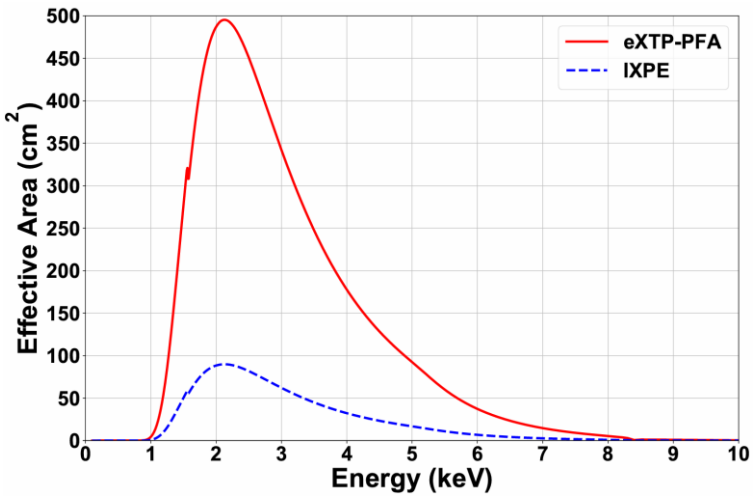
- Polarimetry Focusing Array (PFA) × 3

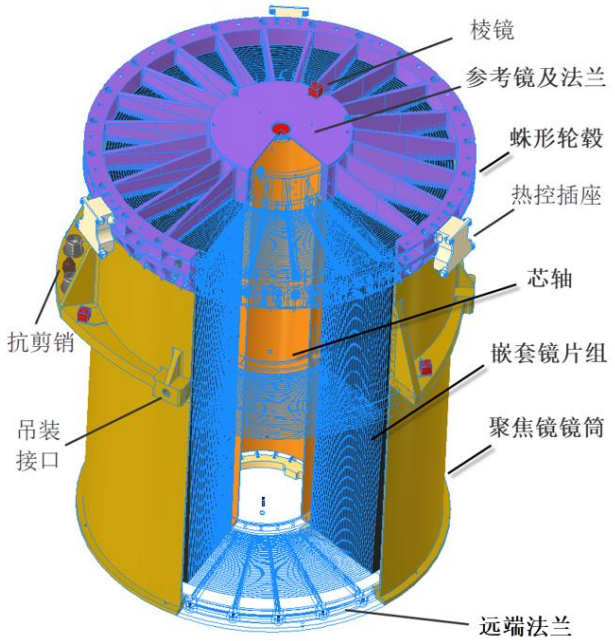
Optics



47 shells nickel electroforming mirrors







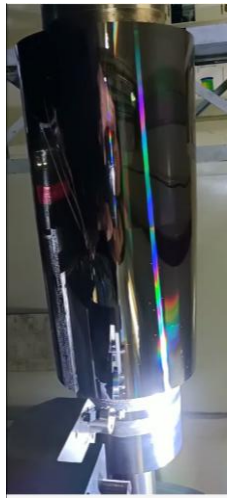
	Specifications	
	SFA	PFA
On-axis eff area	799 cm^2 @ 1.5 keV 583 cm^2 @ 6 keV	862 cm^2 @ 3 keV
On-axis HPD	≤ 1′	≤ 30″
Diameter	226~500 mm	
Shells	47	
FoV	> 12′	
Focal length	5250 ± 50 mm	
Mass	≤ 150 kg	

Optics – electroformed nickel replication mirrors

1 Rough turning

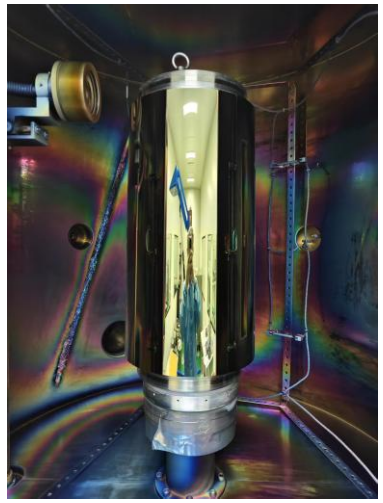
2 Electroless plating (Ni/P alloy)

3 Precision turning



4 Superpolishing

5 Coating (TiN / Au)

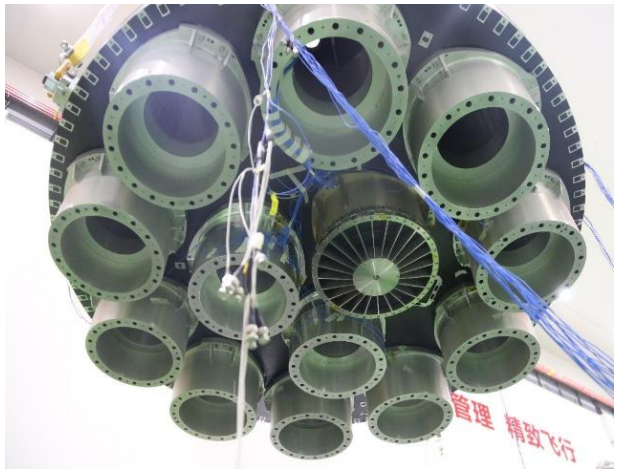


6 Electroforming (Ni)

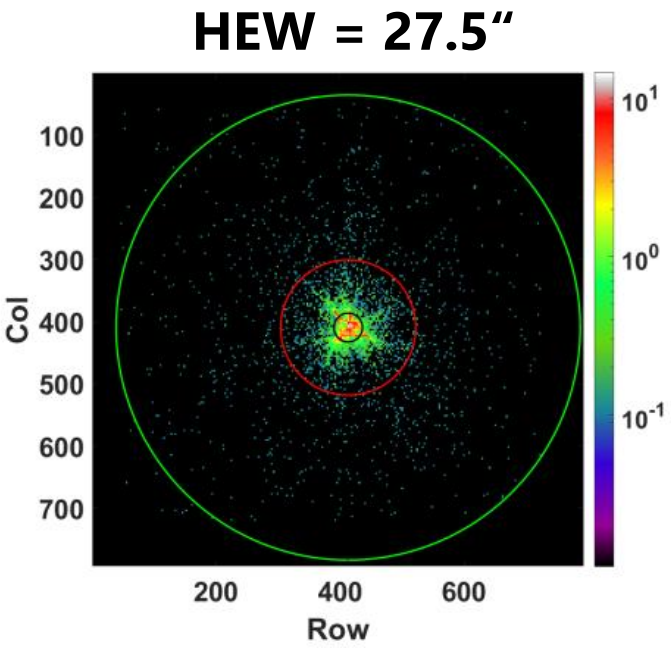
7 Demolding

Manufacturing Processes

Optics

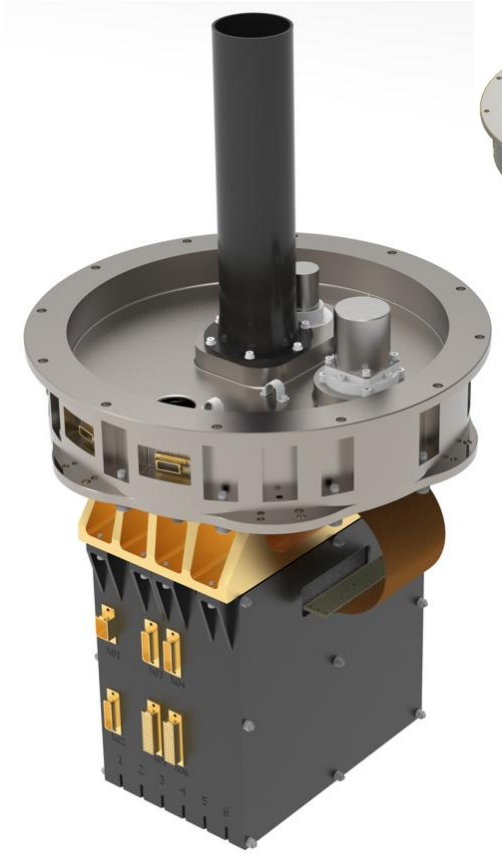


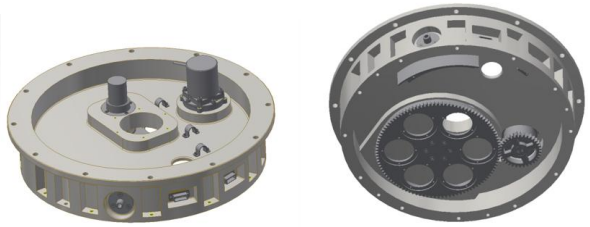
Mechanical tests



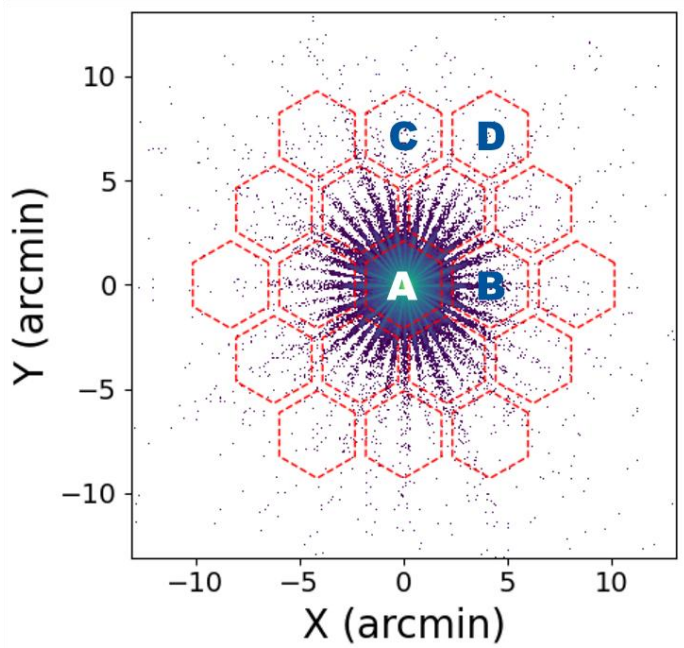
The first PFA prototype

SDD detectors



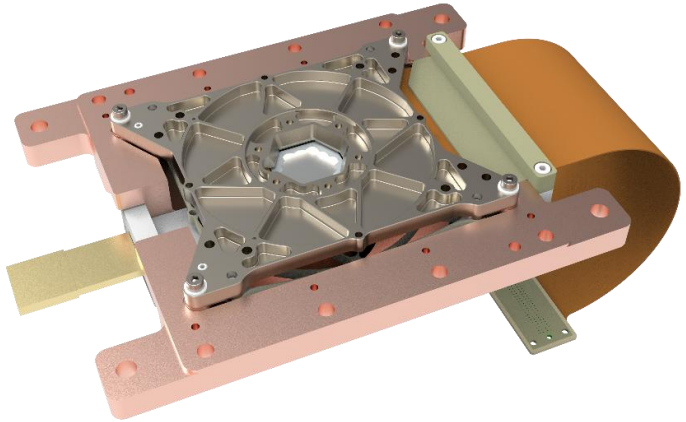


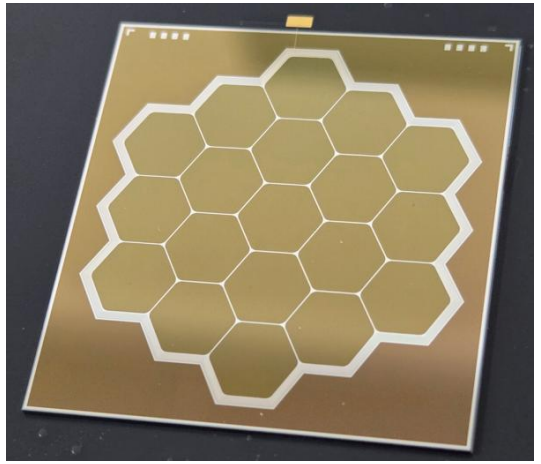
Filter wheel



Pixel ID	Number of pixels	PSF fraction per pixel
A	1	92.85%
B	6	0.48%
C	6	0.05%
D	6	0.03%
Out-of-FoV		3.79%

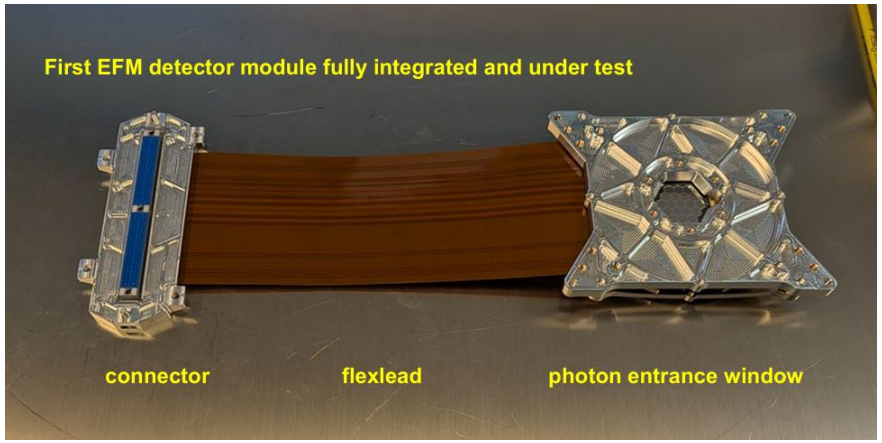
SDD detector

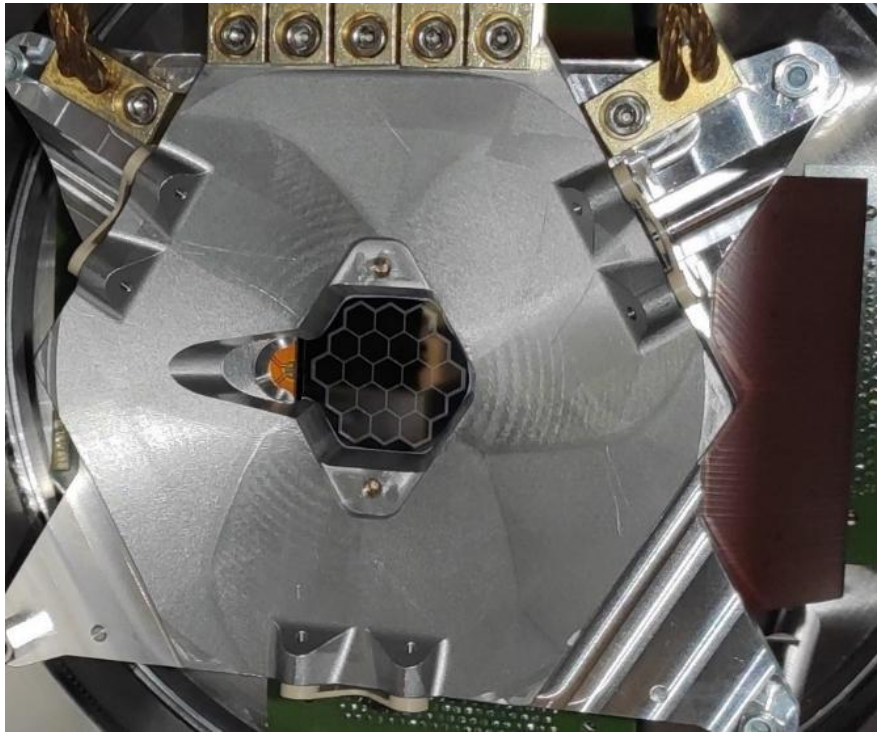




SDD chip

SDD detectors @ MPE



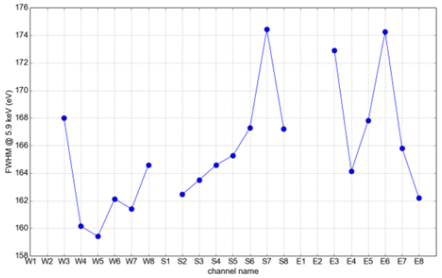


Measurement Analysis EFM – Energy Resolution

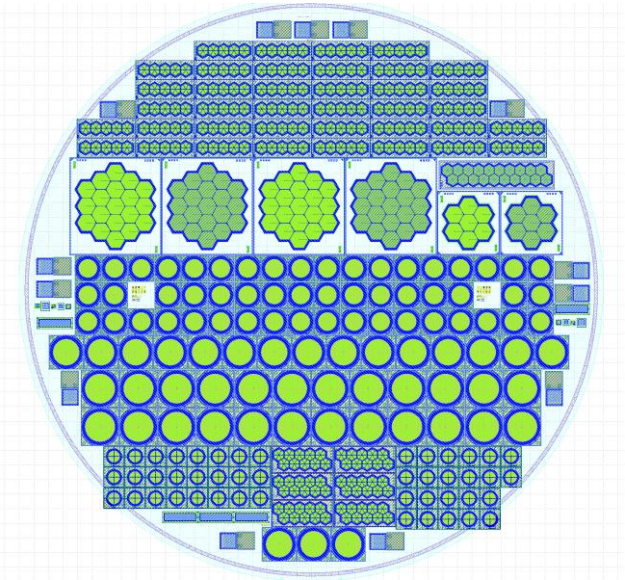
Pixel	FWHM (eV)
W3	168
W4	160
W5	159
W6	162
W7	161
W8	164
S2	162
S3	163
S4	164
S5	165
S6	167
S7	174
S8 (central)	167

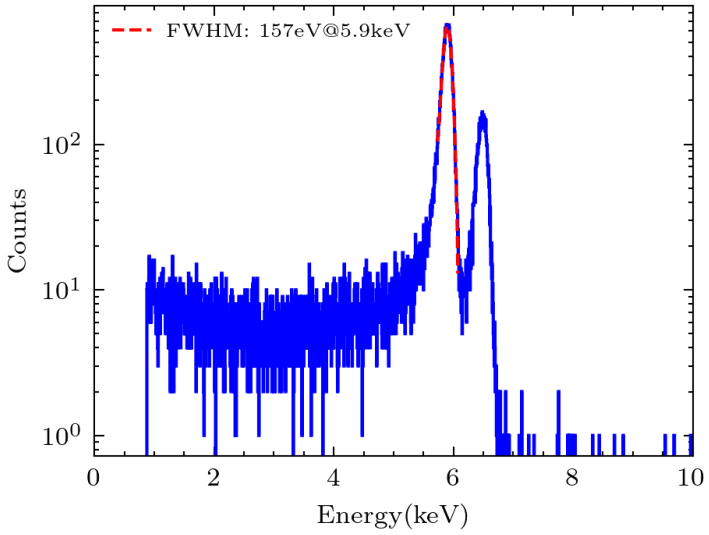
Pixel	FWHM (eV)
E3	173
E4	164
E5	167
E6	175
E7	165
E8	162
Mean	165

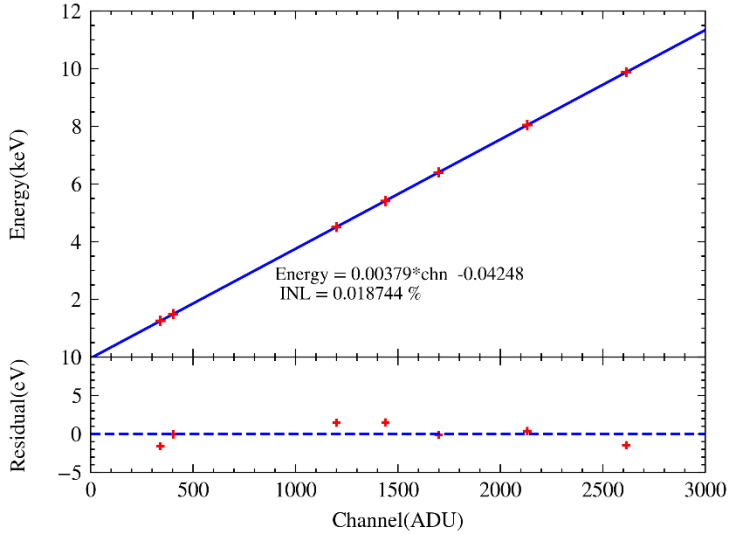
Shaping time: 1.4 µs
Temperature: -46 °C
pile-up rejection (PUR) off

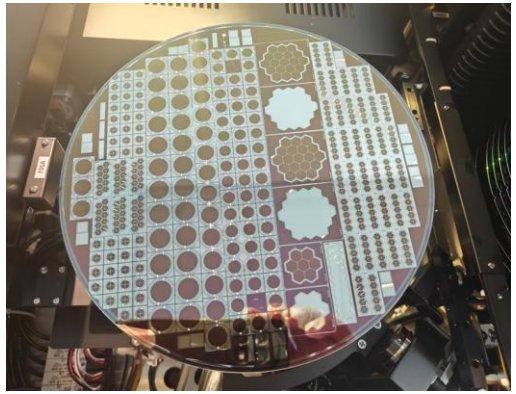


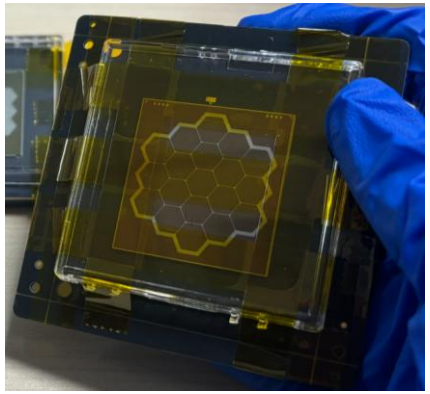
SDD detectors @ IHEP

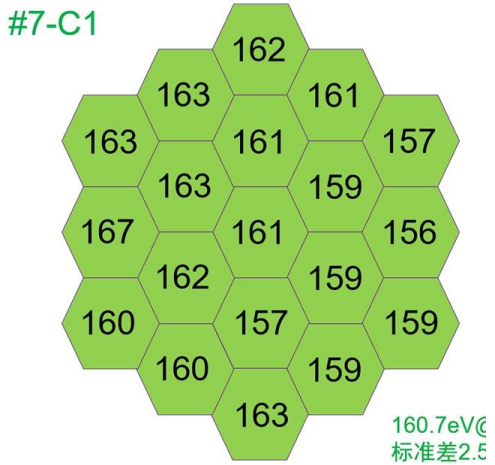






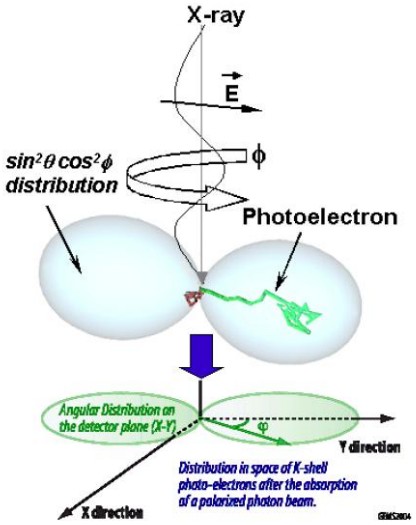


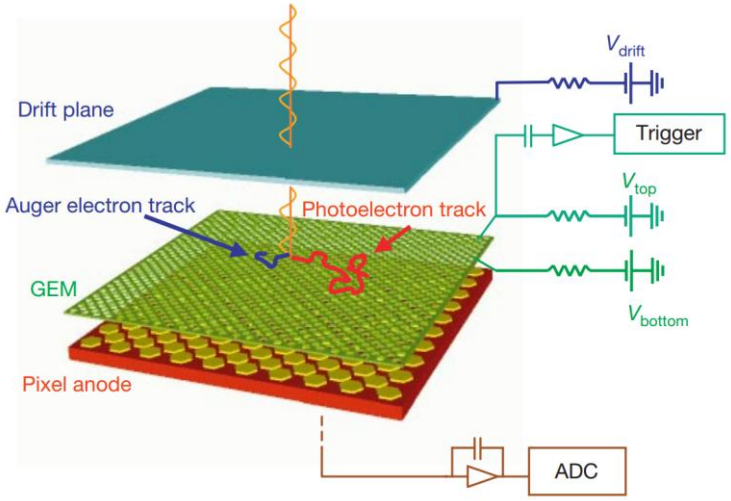




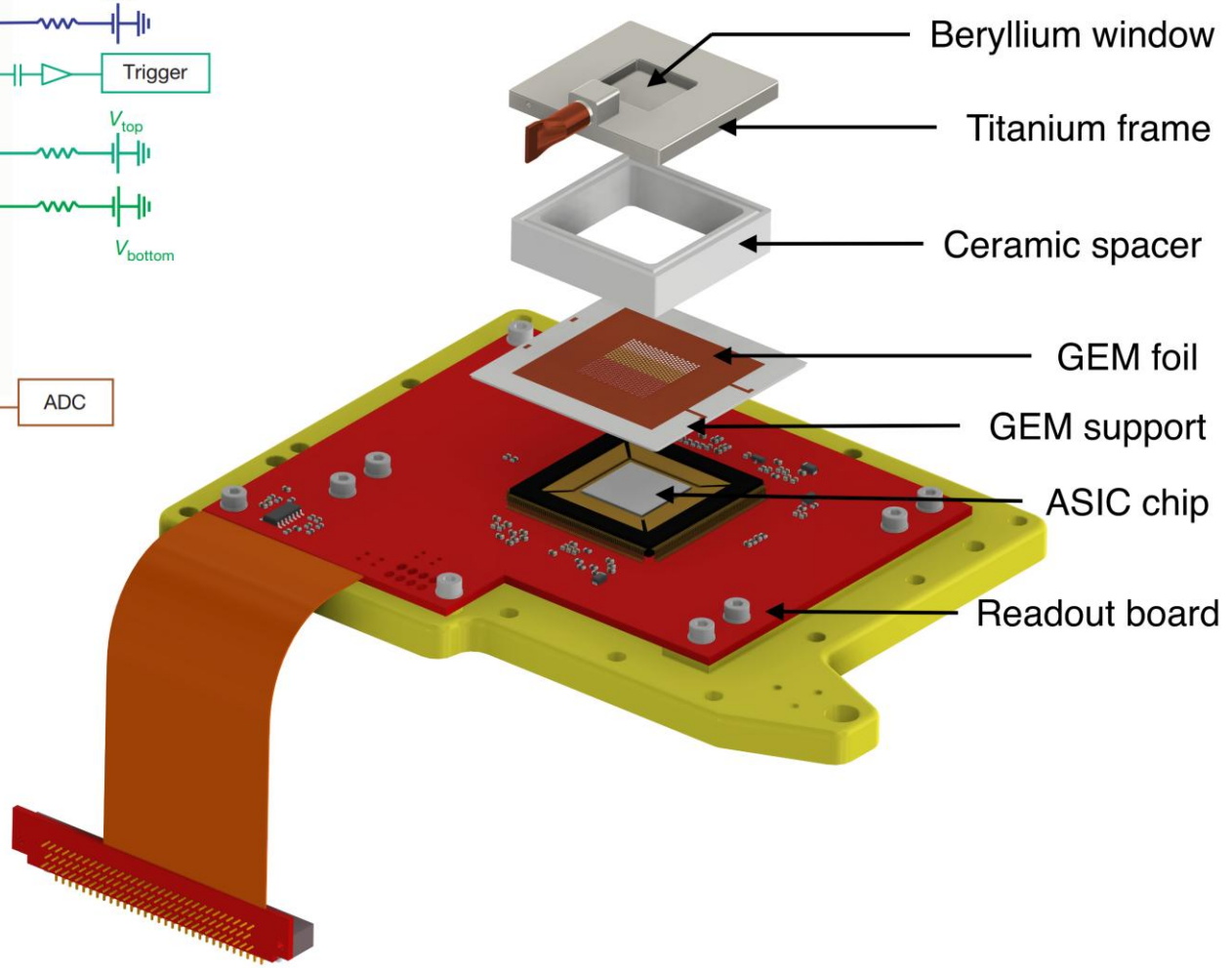
Measured FWHM (eV)

Gas pixel detectors

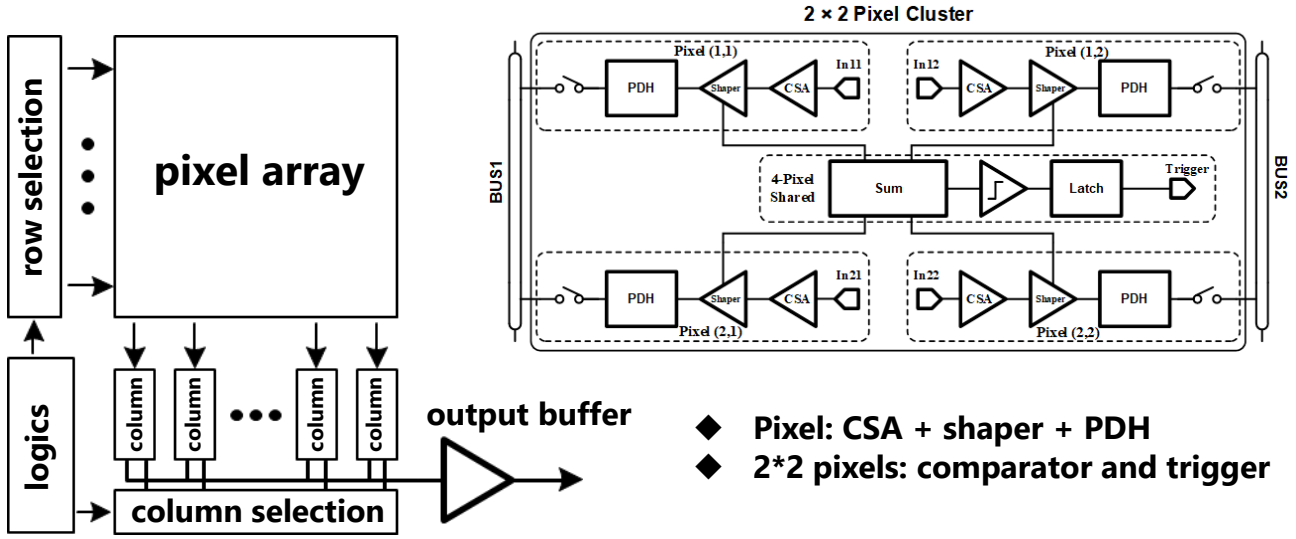




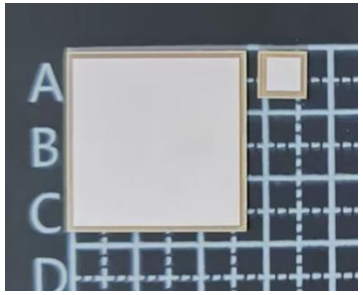
$$\frac{\partial\sigma}{\partial\Omega} = r_0^2 \frac{Z^5}{137^4}\left(\frac{mc^2}{h\nu}\right)^{7/2} \frac{4\sqrt{2}\sin^2(\theta)\cos^2(\varphi)}{(1-\beta\cos(\theta))^4}$$

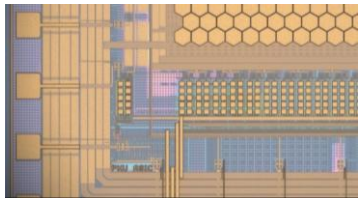


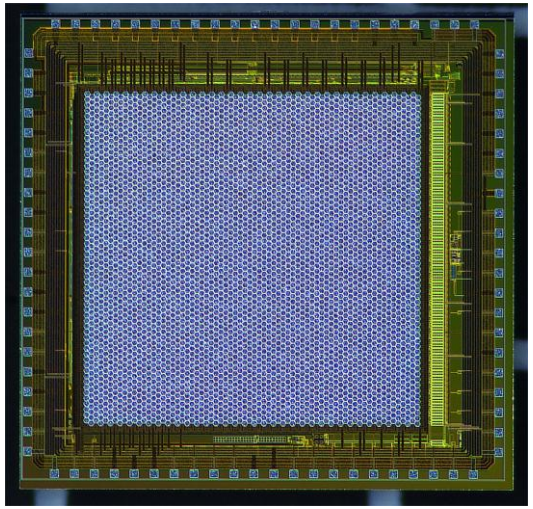
Gas pixel detectors



- Pixel: CSA + shaper + PDH
- 2*2 pixels: comparator and trigger

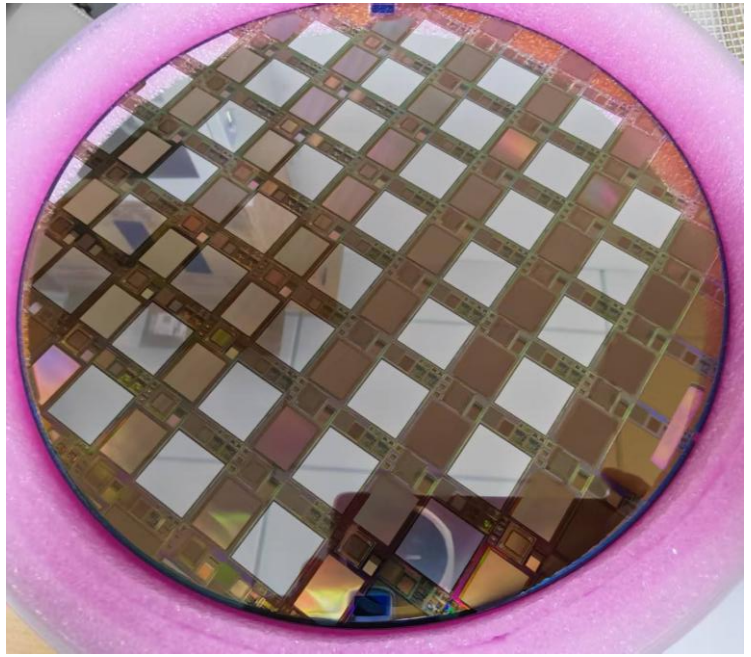




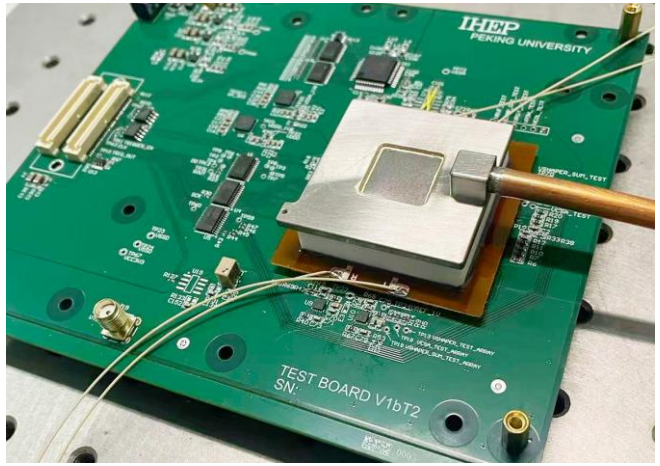


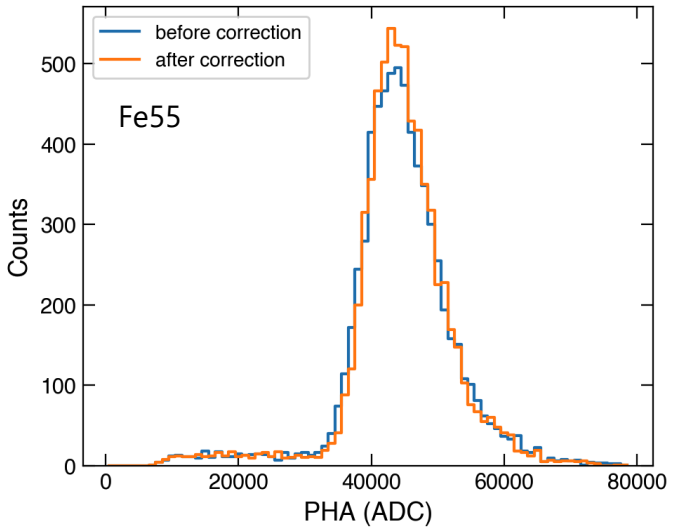
Pixels	≥ 304 × 352
Pitch	≤ 50 μm
Readout noise	≤ 30 e^- ENC
Dynamical range	30 ke^-
Lower threshold	~150 e^-
Readout frequency	≥ 10 MHz
Power	≤ 2 W

1a 60 * 70 pixels (2025.03)
1b 60 * 70 pixels (2026.02)
2a 304 * 352 pixels (2026.04-06)
2b 304 * 352 pixels (2026.10 expected)
2c 304 * 352 pixels (2027.05 expected)



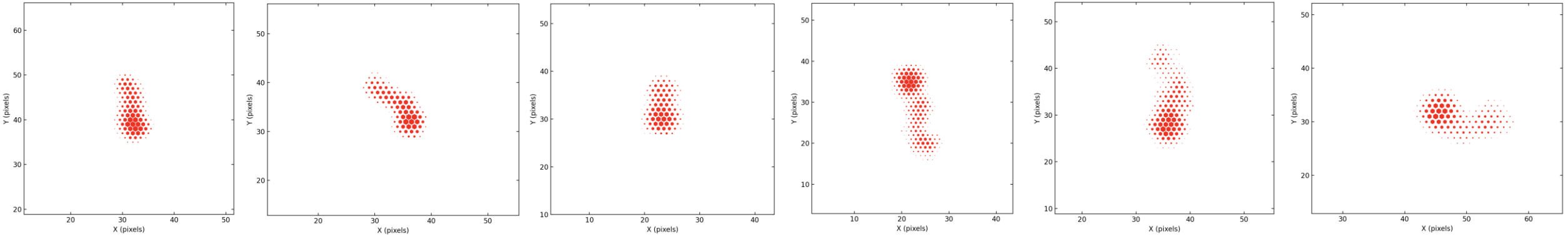
Gas pixel detectors





- ✓ **No cross talk**
- ✓ **No pedestal variation**
- ✓ **Good linearity**

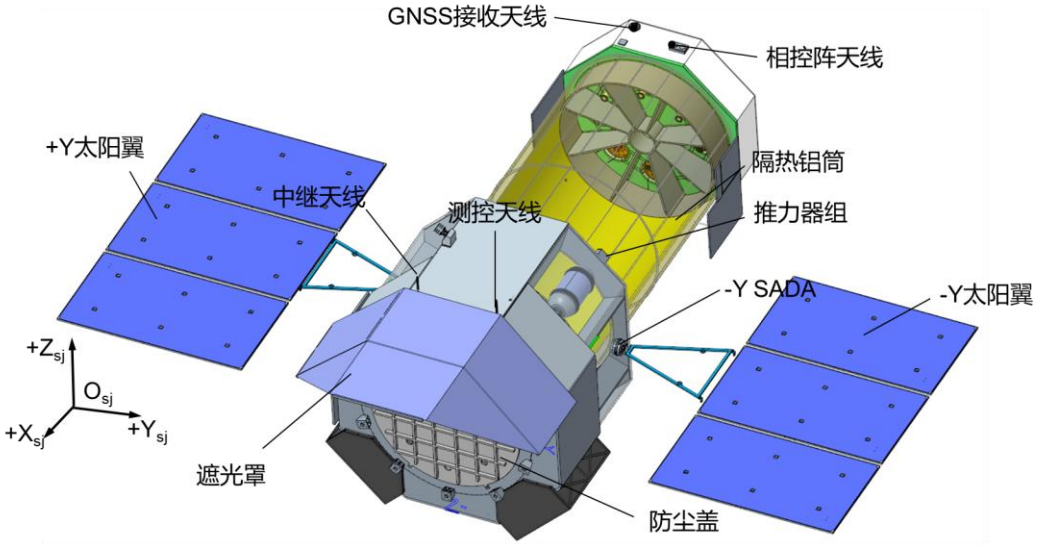
The first test prototype with the 1b ASIC

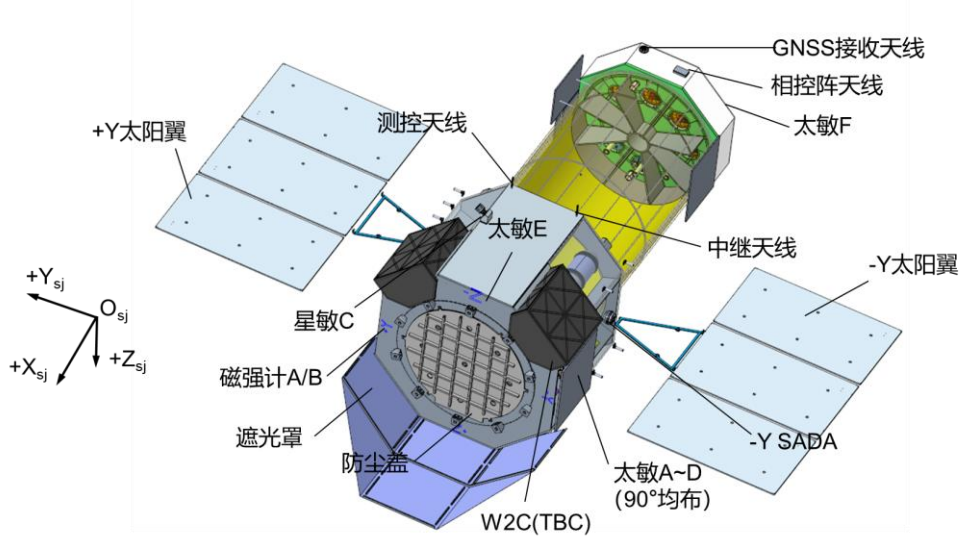


Satellite

Size

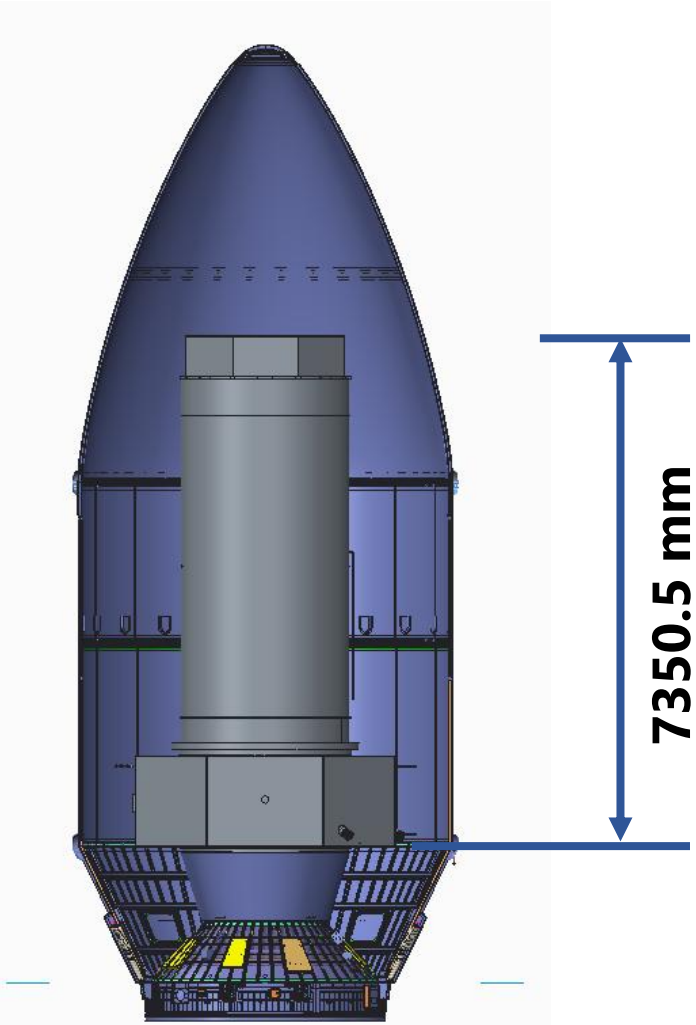
- On orbit: 9448 mm (X) × 11681 mm (Y) × 4154 mm (Z)
- Launch state: Φ4500 mm × 7202 mm



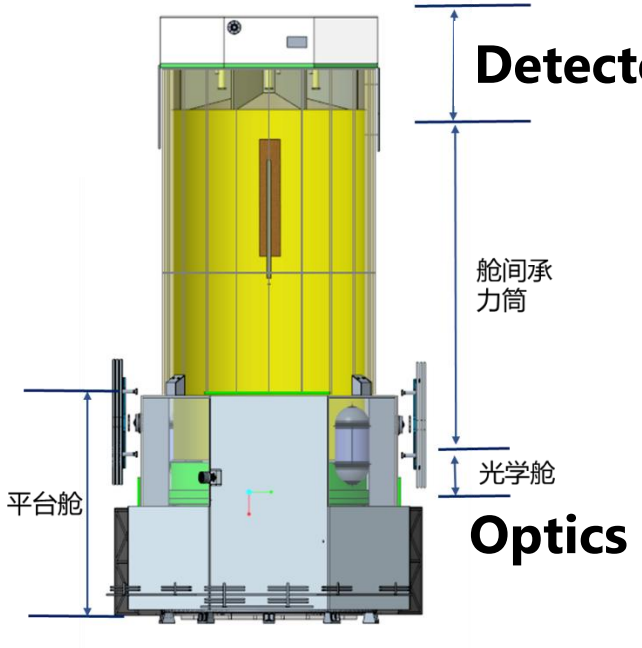


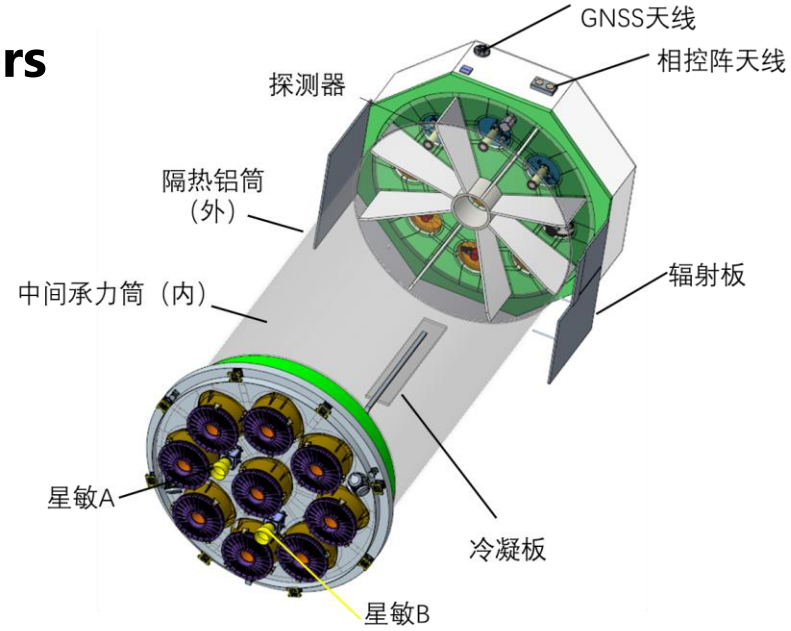
- Solar Array Drive Assembly (SADA)
- Control Moment Gyroscope (CMG)
- Maneuver: 90° repointing and stabilization within 3 minutes
- Storage + data transfer: continuous for 1 Crab; 18 ks per two days for 15 Crab

Launch vehicle



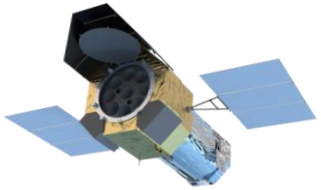
CZ-8A (up to 7 tons)



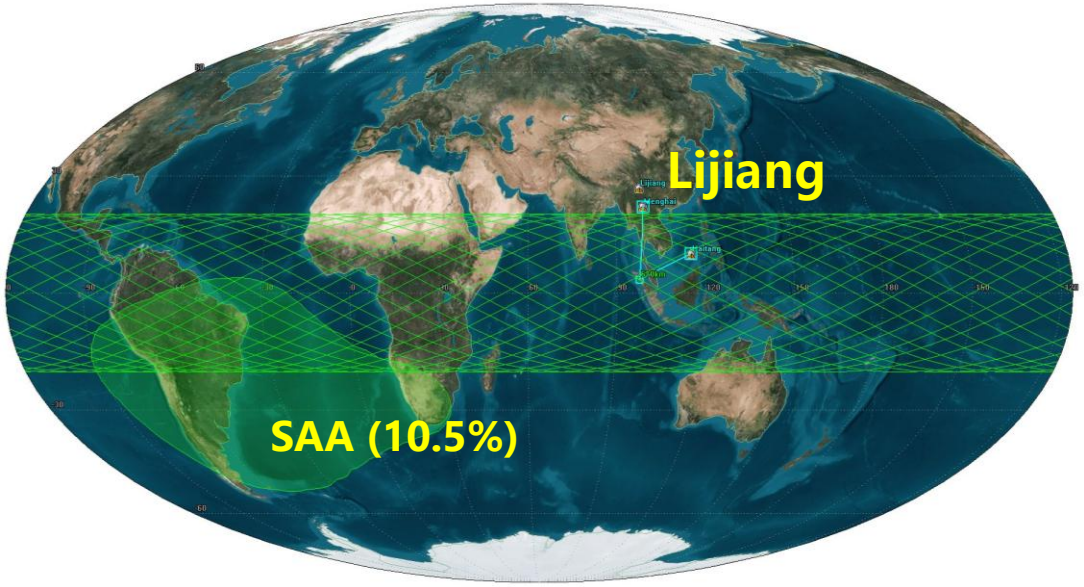


Total weight: about 5 tons

Orbits and data transmission

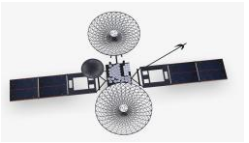


Circular LEO: altitude 610 km, inclination 20°



Data transmission

Short messages

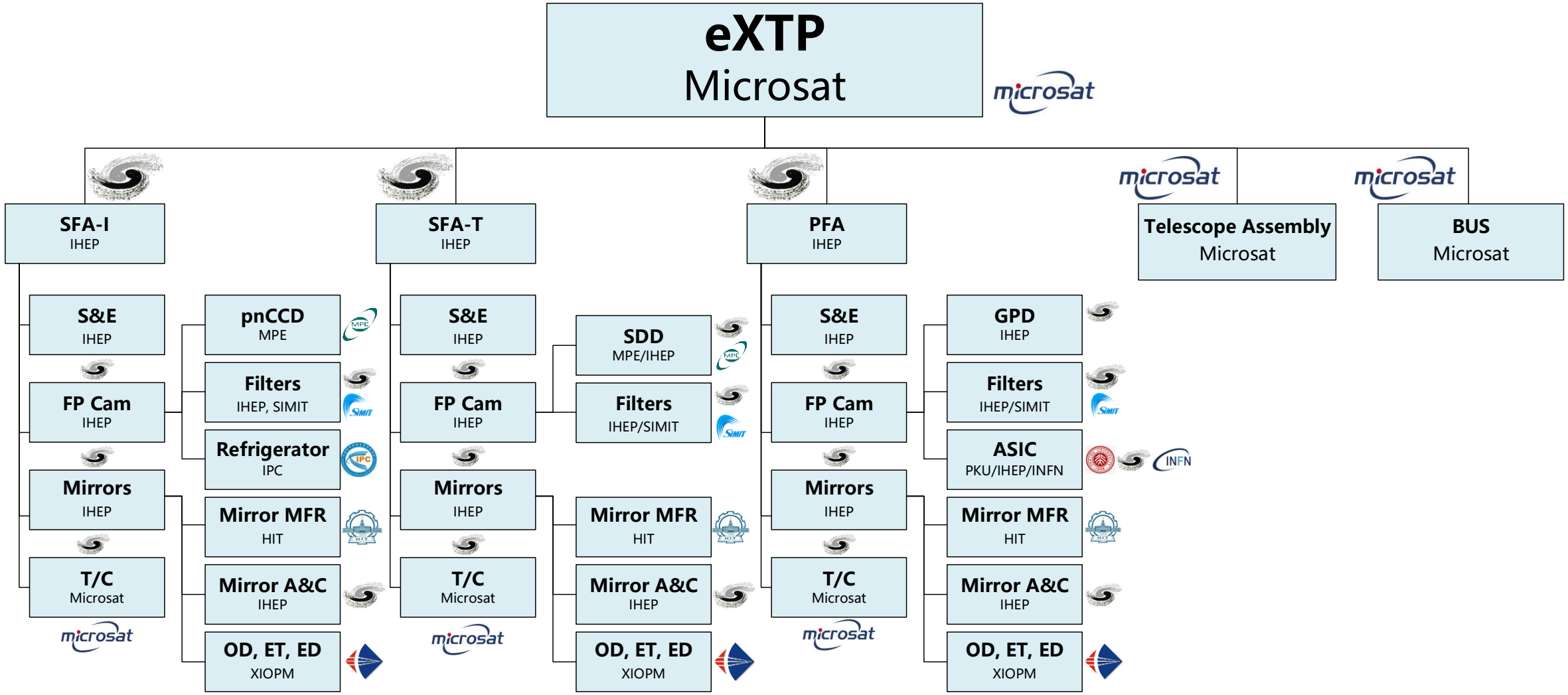


Relay

Beidou

Lijiang station	
Daily passes	4.5
Total time per day	27.54 min
Maximum time gap	22.38 h

Instrumentation team



International consortium

International Science Working Groups

China

General Coordinator: Mingyu Ge, Ping Zhou

Europe

General Coordinator: Andrea Santangelo, Silvia Zane

coordinators		coordinators
Ang Li, Guobao Zhang, Wenfei Yu	WG1: Dense Matter	Anna Watts， Sebastien Guillot
Lijun Gou, Qingcui Bu, Cosimo Bambi	WG2: Extreme Gravity	Alessandra De Rosa, Phil Uttley
Mingyu Ge, Long Ji	WG3: Strong Magnetism	Roberto Taverna, Sergey Tsygankov
Xuefeng Wu, Renxin Xu， Shuxu Yi， Wen Zhao	WG4: TDMMA	Giulia Stratta, Simone Dall'Osso
Ping Zhou , Liang Zhang, Jirong Mao	WG5: Observatory Science	Enrico Bozzo , Alessandro Patruno

PART 03

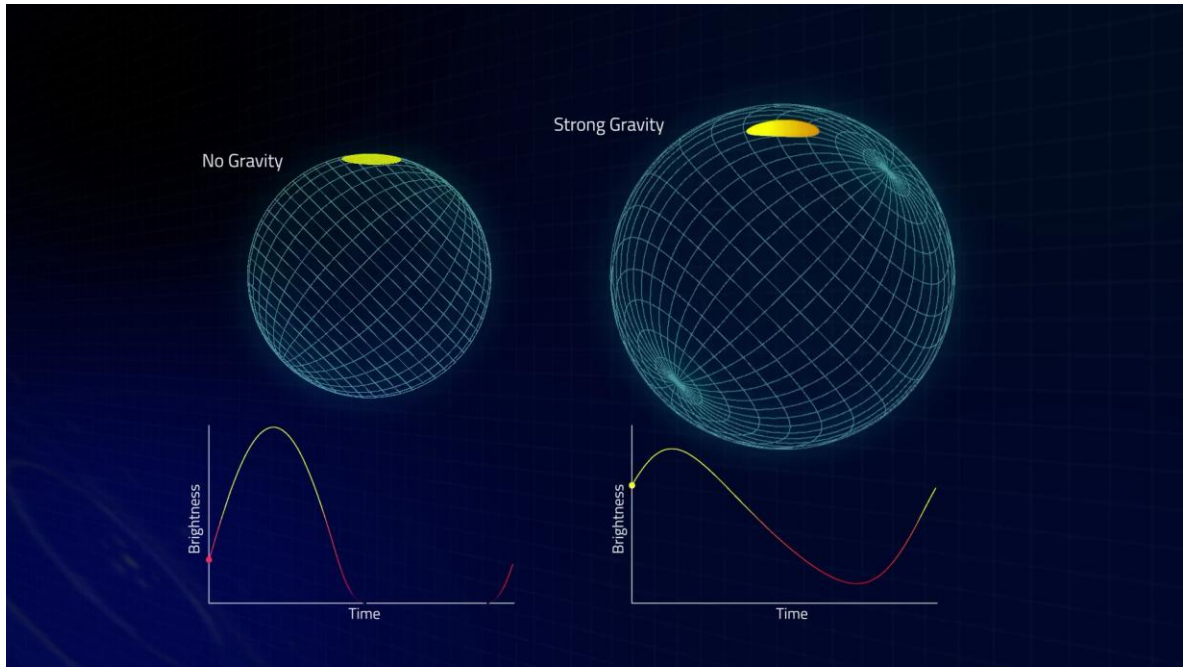
Science Cases

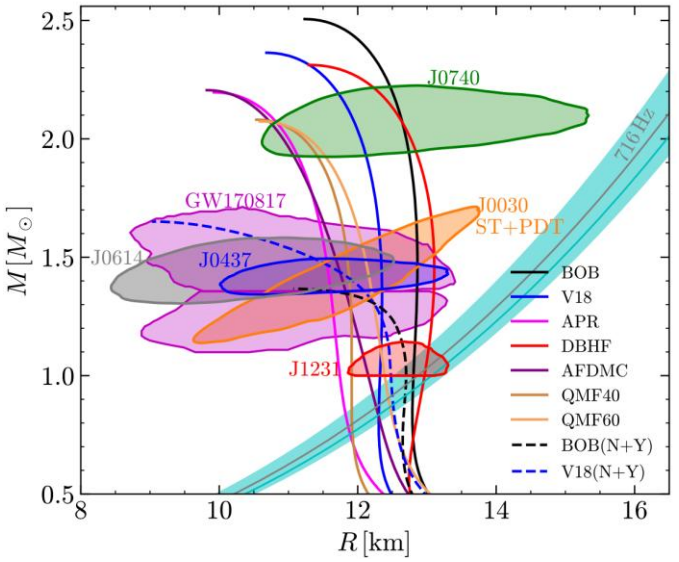
Sciences with eXTP

- **White papers on**
  - Dense matter
  - Strong gravity
  - Strong magnetism
  - Time-domain and multi-messenger
  - Observatory science

The enhanced X-ray Timing and Polarimetry mission—eXTP for launch in 2030 Zhang, S. N., Santangelo, A., Xu, Y. et al. 2025, SCPMA, 68, 119502
Dense matter in neutron stars with eXTP Li, A., Watts, A. L., Zhang, G. et al. 2025, SCPMA, 68, 119503
Probing the strong gravity region of black holes with eXTP Bu, Q., Bambi, C., Gou, L. et al. 2025, SCPMA, 68, 119504
Physics of strong magnetism with eXTP Ge, M., Ji, L., Taverna, R. et al. 2025, SCPMA, 68, 119505
Prospects for time-domain and multi-messenger science with eXTP Yi, S.-X., Zhao, W., Xu R.-X. et al. 2025, SCPMA, 68, 119506
Observatory science with eXTP Zhou, P., Mao, J., Zhang, L. et al. 2025, SCPMA, 68, 119507

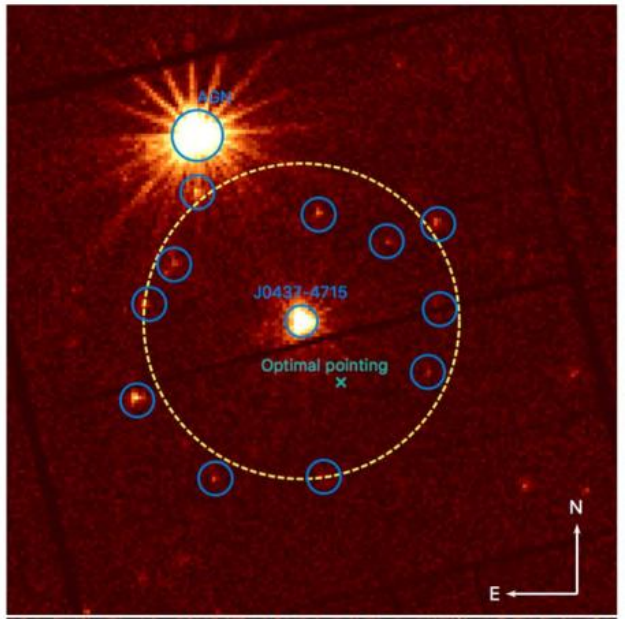
EoS of NSs – Pulse Profile Modeling





Bogdanov et al. 2019;
Riley et al. 2019,2021;
Miller et al. 2019,2021;
Miao et al. 2024;
Choudhury et al.2024;
Mauviard et al. 2025;
Qi et al. 2025;
Miller et al. 2026

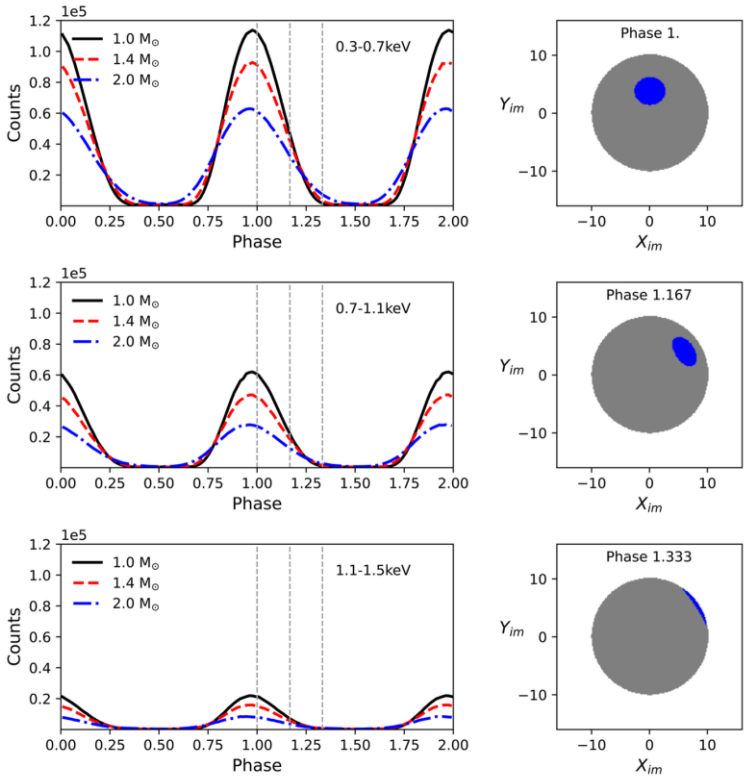
Pulsar	Mass ($M_\odot$)	Radius (km)	Distance (kpc)
J0030+0451	$1.44^{+0.15}_{-0.14}$	$13.02^{+1.24}_{-1.06}$	0.28 ± 0.06
J0437-4715	1.418 ± 0.034	$11.36^{+0.95}_{-0.63}$	0.157 ± 0.001
J0740+6620	2.073 ± 0.069	$12.49^{+1.28}_{-0.88}$	1.136 ± 0.163
J1231-1411	$1.04^{+0.05}_{-0.03}$	$12.6^{+0.3}_{-0.3}$	0.44 ± 0.05
J0614-3329	$1.44^{+0.06}_{-0.07}$	$10.29^{+1.01}_{-0.86}$	0.585 ± 0.045



XMM+NICER is needed

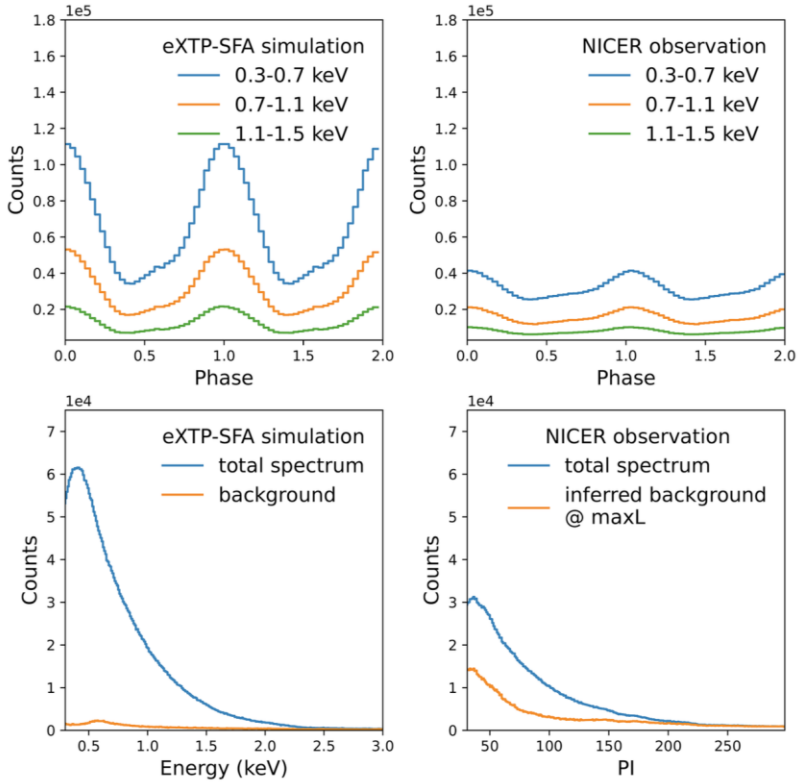
Expected results with eXTP SFA

1Ms observation with eXTP-SFA



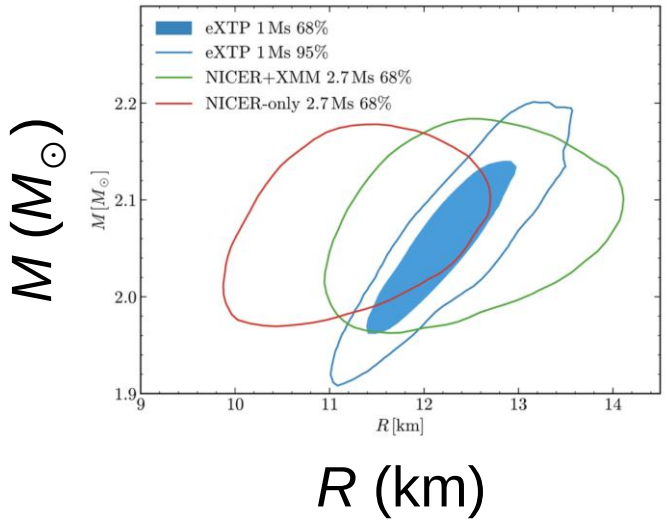
Hot spot with a single temperature

PSR J0437-4715: SFA vs. NICER



Much higher S/N

Constraint on *M-R*

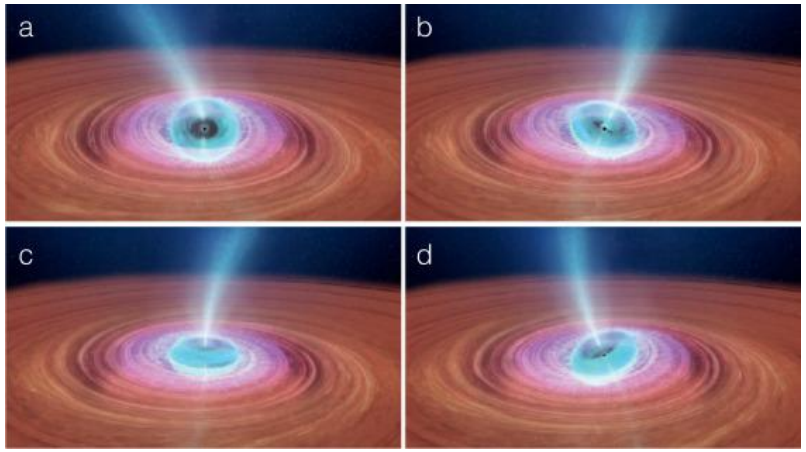


M ($M_\odot$)

R (km)

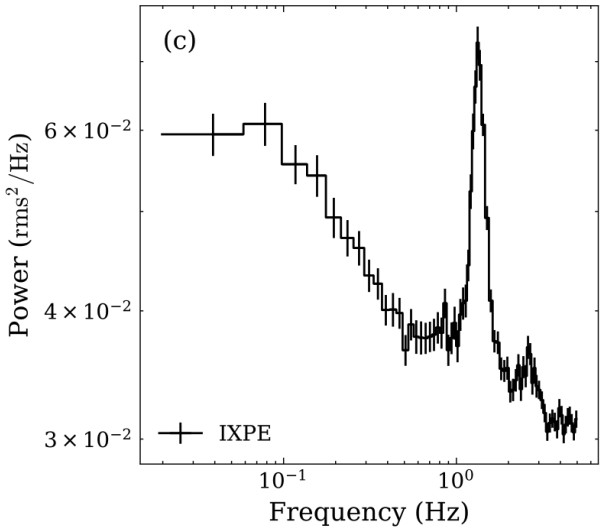
The nature of low-frequency QPOs

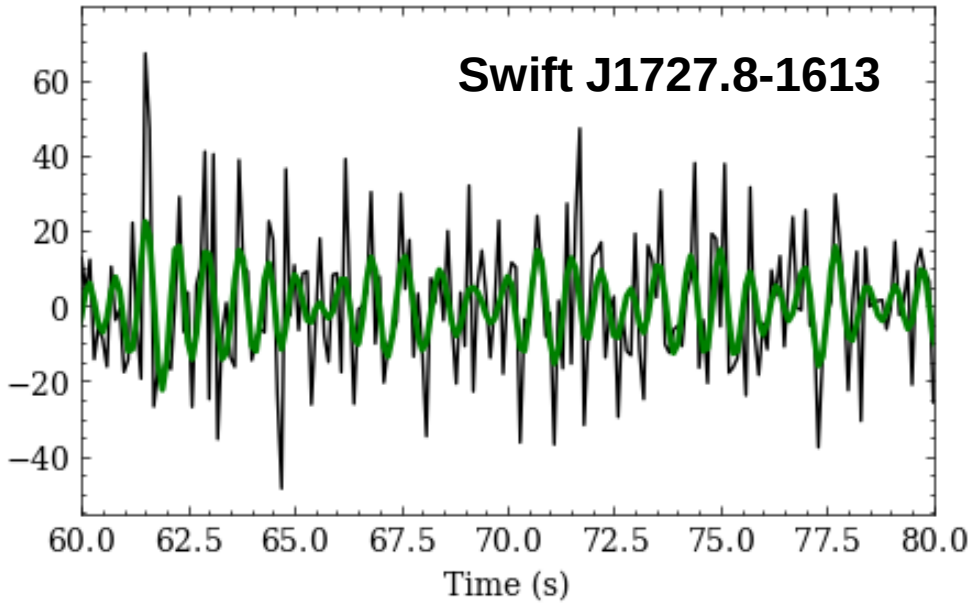
QPOs: instability or geometric modulation?

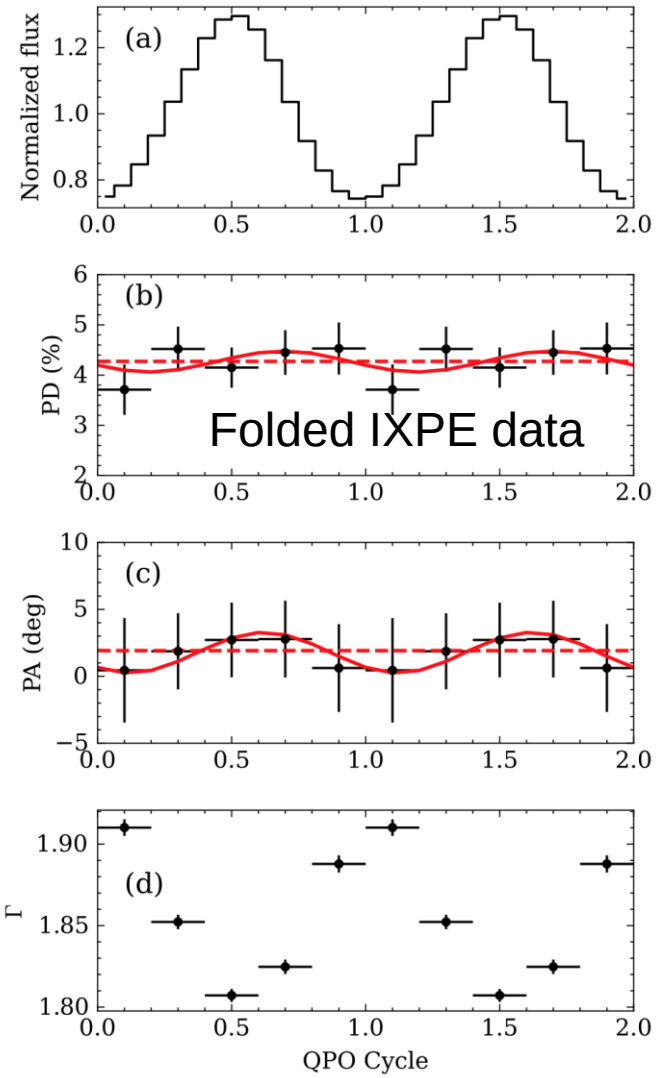


Lense-Thirring precessing

(Ingram et al. 2017; Ingram & Maccarone 2017; Ingram & Motta 2019)

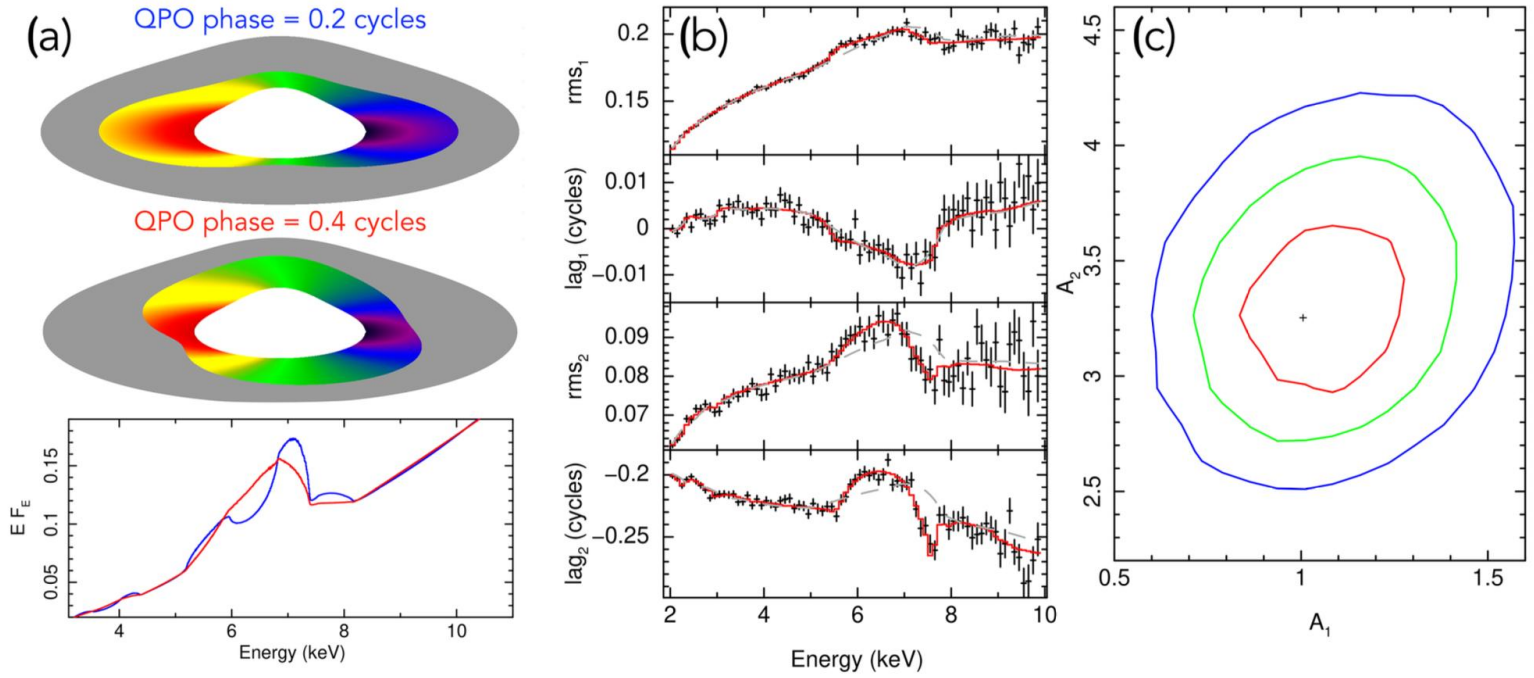






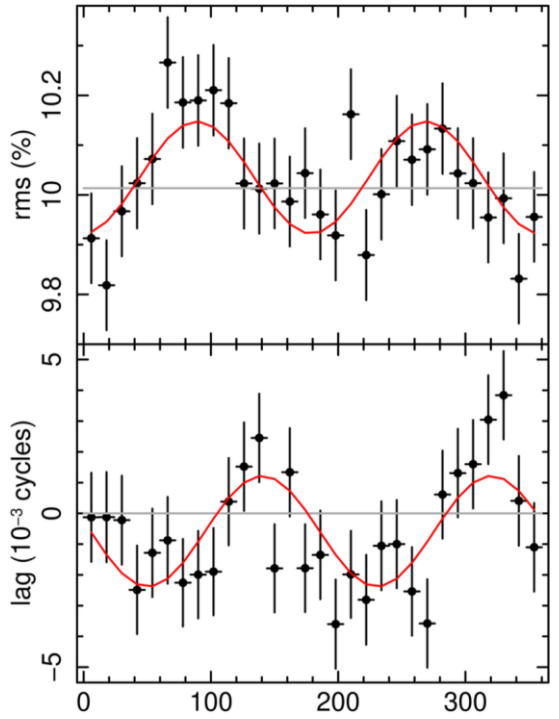
(Zhao et al. 2024, ApJ, 961, 42)

The nature of low-frequency QPOs



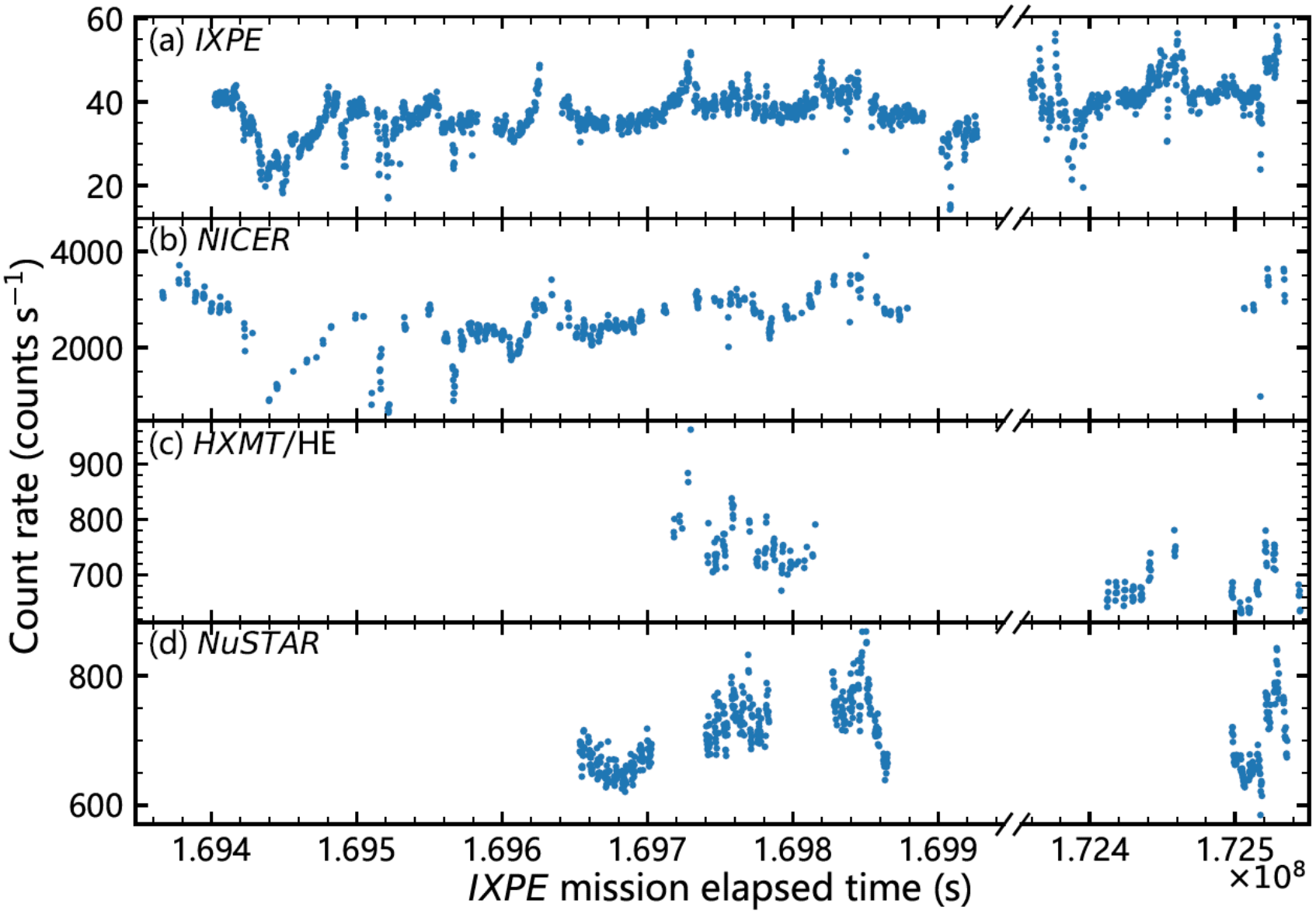
50 ks eXTP observation of a 250 mCrab BHXRB

SFA phase lag



PFA modulation angle

Joint Observations



Overlapped time fraction

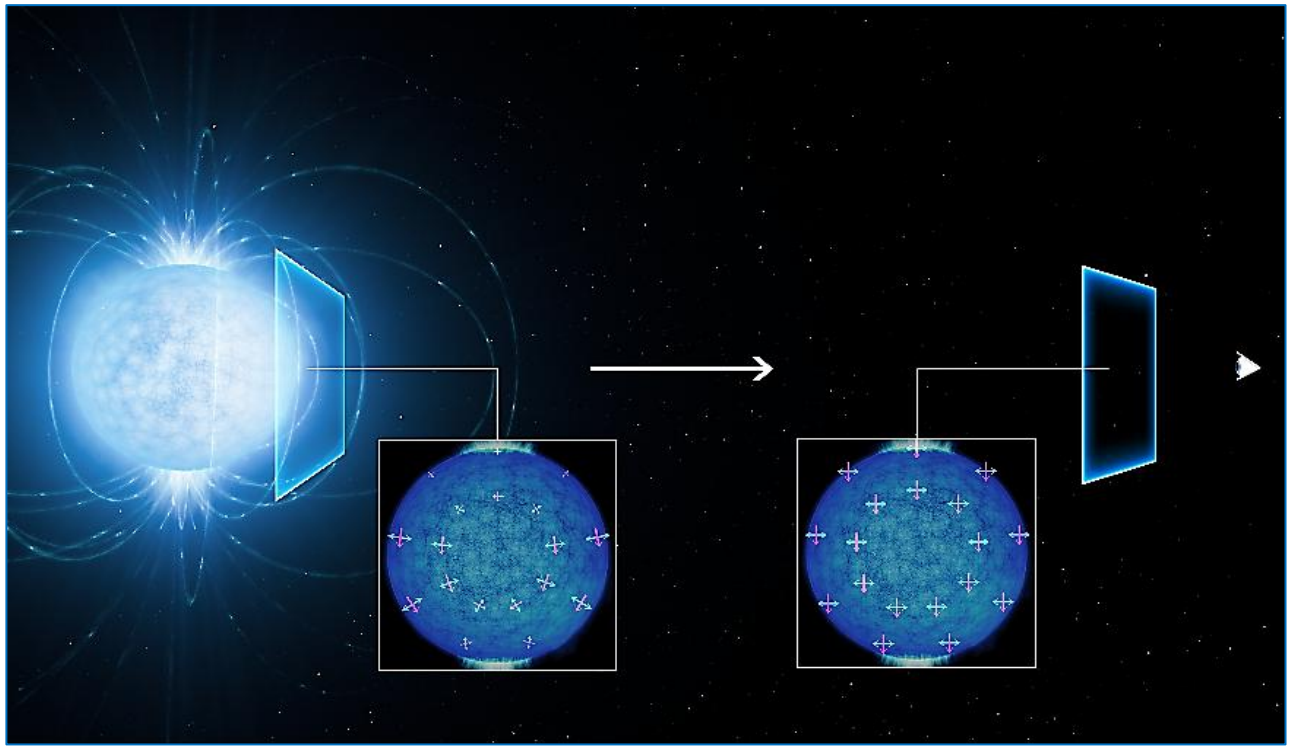
12%

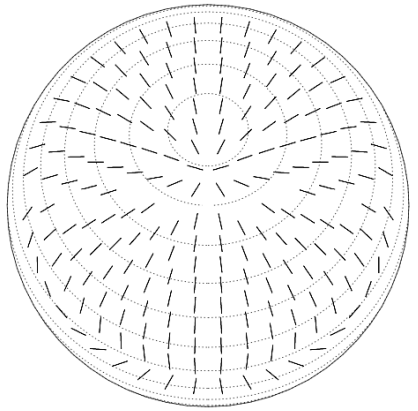
8%

14%

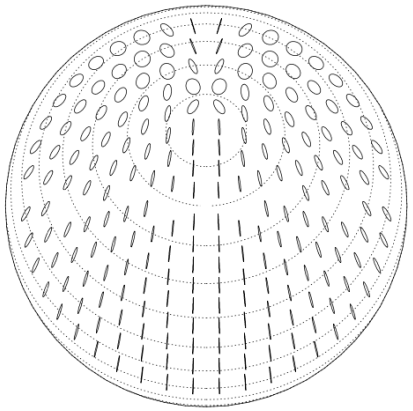
QED effect: vacuum birefringence

$$r_{\rm pl} \approx 80 \left(\frac{B_{\rm p}}{10^{14}\,{\rm G}}\right)^{2/5} \left(\frac{E}{1\,{\rm keV}}\right)^{1/5} \left(\frac{R_{\rm NS}}{10\,{\rm km}}\right)^{1/5} R_{\rm NS}$$





PA on surface



PA observed

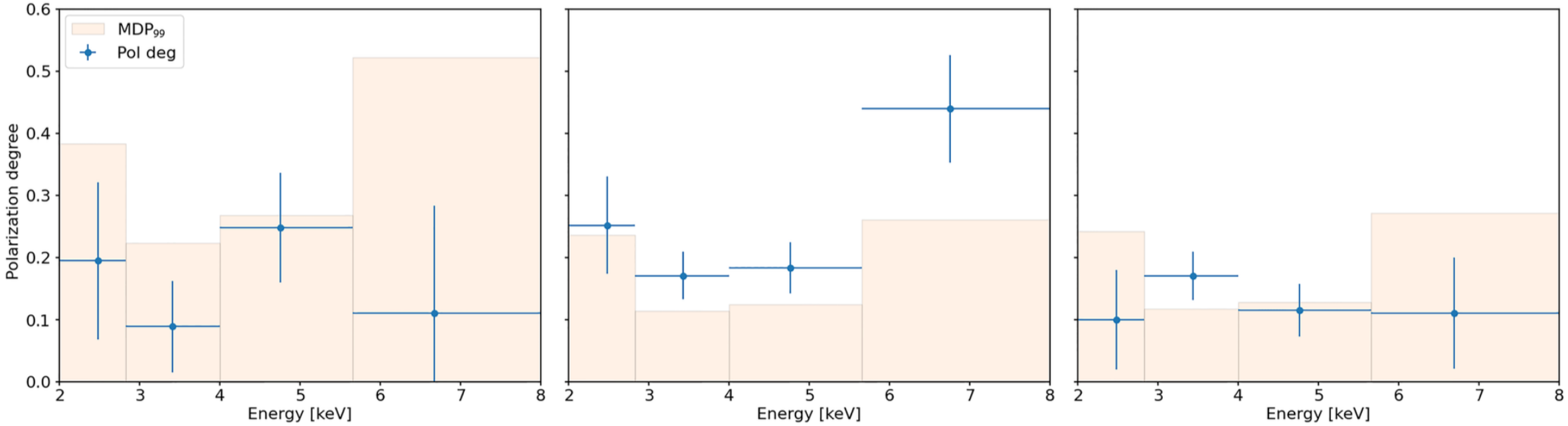
High degree of linear polarization (40% - 80%) observed in the magnetar 1E 1547.0-5408
Stewart et al. (arXiv:2509.19446)

Testing the vacuum birefringence

IXPE

eXTP, QED on

eXTP, QED off

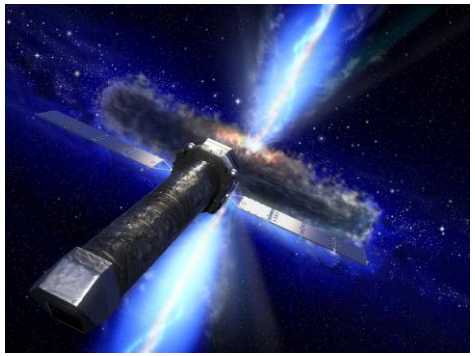


1Ms observation of SGR 1806-20 (transient magnetar)

Summary

- **eXTP – a future flagship X-ray observatory**

eXTP
(expected in 2030)
Large Area Spectro-Timing-Polarimetry
black holes & neutron stars



NewAthena
(not before 2037?)
fine spectral resolution
galaxy evolution

THANK YOU!