

# THE ENHANCED X-RAY TIMING AND POLARIMETRY (EXTP) MISSION

MARCO FEROCI

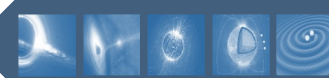
IAPS/INAF & INFN/RM2, ROME, ITALY

ON BEHALF OF THE EXTP CONSORTIUM

enhanced x-ray timing and polarimetry mission



- ❑ A flagship X-ray observatory mission, being developed by the Chinese Academy of Sciences, with a large contribution by a European Consortium. ESA is considering a MoO participation.
- ❑ Currently in its Phase B2 study (I-SRR successfully completed). The launch date is planned in 2029, for a minimum mission lifetime of 5 years (goal 8 years).
- ❑ eXTP is proposed as an observatory open to the worldwide scientific community, with an observing plan based on Core Program observations as well as on a Guest Investigator Program.



## eXTP PI Institute: IHEP/CAS, Beijing

CAS



CNSA



IHEP Beijing



Institute of High Energy Physics  
Chinese Academy of Sciences

Tsinghua University



Tsinghua University

Tongji University



TONGJI UNIVERSITY

CAST Beijing



中国航天

中国空间技术研究院  
China Academy of Space Technology

IAMC Shanghai



Harbin Institute of Technology



Italy



Spain



Germany



France



Switzerland



Czech Republic



Poland



Denmark



The Netherlands

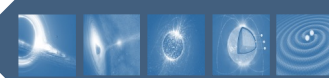


Austria



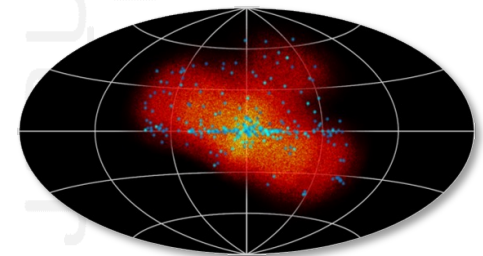
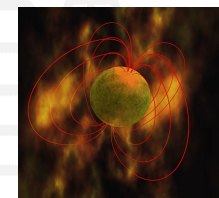
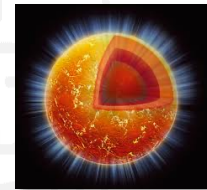
Turkey

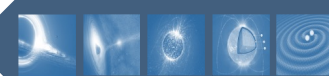




Study of matter under extreme conditions of gravity, density and magnetism. For the first time: simultaneous, high-throughput spectral, timing and polarimetry observations.

- Constrain the **Equation of state** of the supra-nuclear density matter in the interior of neutron stars.
- **Accretion** physics in the **strong-field** regime of **gravity** and tests of General Relativity in neutron stars and black holes over the mass scale.
- Physics of light and matter in the presence of **ultra-strong magnetic fields** in magnetars and X-ray pulsars.
- Multi-purpose **observatory** and wide-field monitoring for transients (and e.m. counterparts of GWs). Rapid automated follow-up.





February 2019 Vol. 62 No. 2: 029503  
Special Issue: The X-ray Timing and Polarimetry Frontier with eXTP

### Dense matter with eXTP

Anna L. Watts<sup>1\*</sup>, WenFei Yu<sup>2</sup>, Juri Poutanen<sup>3,4</sup>, Shu Zhang<sup>5</sup>, Sudip Bhattacharyya<sup>6</sup>, Slavko Bogdanov<sup>7</sup>, Long Ji<sup>8</sup>, Alessandro Patruno<sup>9</sup>, Thomas E. Riley<sup>1</sup>, Pavel Bakala<sup>10</sup>, Altan Baykal<sup>11</sup>, Federico Bernardini<sup>12,13</sup>, Ignazio Bombaci<sup>14,15</sup>, Edward Brown<sup>16</sup>, Yuri Cavocchi<sup>17,18</sup>, Deepto Chakraborty<sup>19</sup>, Jérôme Chenevez<sup>20</sup>, Nathalie Degenaar<sup>1</sup>, Melania Del Santo<sup>21</sup>, Tiziana Di Salvo<sup>22</sup>, Victor Doroshenko<sup>23</sup>, Robert D. Ferdman<sup>24</sup>, Marco Feroci<sup>25</sup>, Angelo F. Gambino<sup>22</sup>, MingYu Ge<sup>5</sup>, Svenja K. Greif<sup>26,27</sup>, Sebastien Guillot<sup>28</sup>, Can Gungor<sup>5</sup>, Dieter H. Hartmann<sup>29</sup>, Kai Hebel<sup>26,27</sup>, Alexander Heger<sup>30</sup>, Jeroen Homan<sup>19</sup>, Rosario Iaria<sup>22</sup>



February 2019 Vol. 62 No. 2: 029506  
Special Issue: The X-ray Timing and Polarimetry Frontier with eXTP

### Observatory science with eXTP

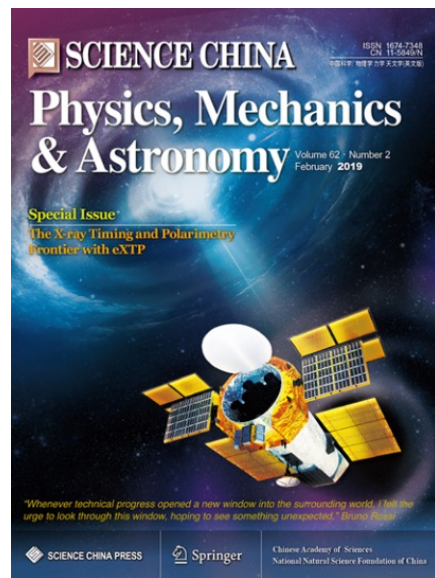
Jean J. M. in 't Zand<sup>1\*</sup>, Enrico Bozzo<sup>2</sup>, JinLu Qu<sup>3</sup>, Xiang-Dong Li<sup>4</sup>, Lorenzo Amati<sup>5</sup>, Yang Chen<sup>6</sup>, Immacolata Donnarumma<sup>6,7</sup>, Victor Doroshenko<sup>8</sup>, Stephen A. Drake<sup>9</sup>, Margarita Hernanz<sup>10</sup>, Peter A. Jenke<sup>11</sup>, Thomas J. Maccarone<sup>12</sup>, Simin Mahmoodifar<sup>13</sup>, Domitilla de Martino<sup>13</sup>, Alessandra De Rosa<sup>14</sup>, Elena M. Rossi<sup>14</sup>, Antonia Rowlinson<sup>15,16</sup>, Gloria Sala<sup>17</sup>, Giulia Stratta<sup>18</sup>, Thomas M. Tauris<sup>19</sup>, Joern Wilms<sup>20</sup>, XueFeng Wu<sup>21</sup>, Ping Zhou<sup>15,14</sup>, Iván Agudo<sup>22</sup>, Diego Altamirano<sup>23</sup>, Jean-Luc Atteia<sup>24</sup>, Nils A. Andersson<sup>25</sup>, M. Cristina Baglio<sup>26</sup>, David R. Ballantyne<sup>27</sup>, Altan Baykal<sup>28</sup>



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Special Issue: The X-ray Timing and Polarimetry Frontier with eXTP

### The enhanced X-ray Timing and Polarimetry mission—eXTP

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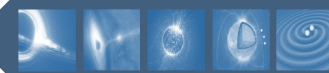


## 2019 White Papers for eXTP science case and mission:

- Dense Matter
- Strong Field Gravity
- Strong Magnetism
- Observatory Science
- Instrument and mission

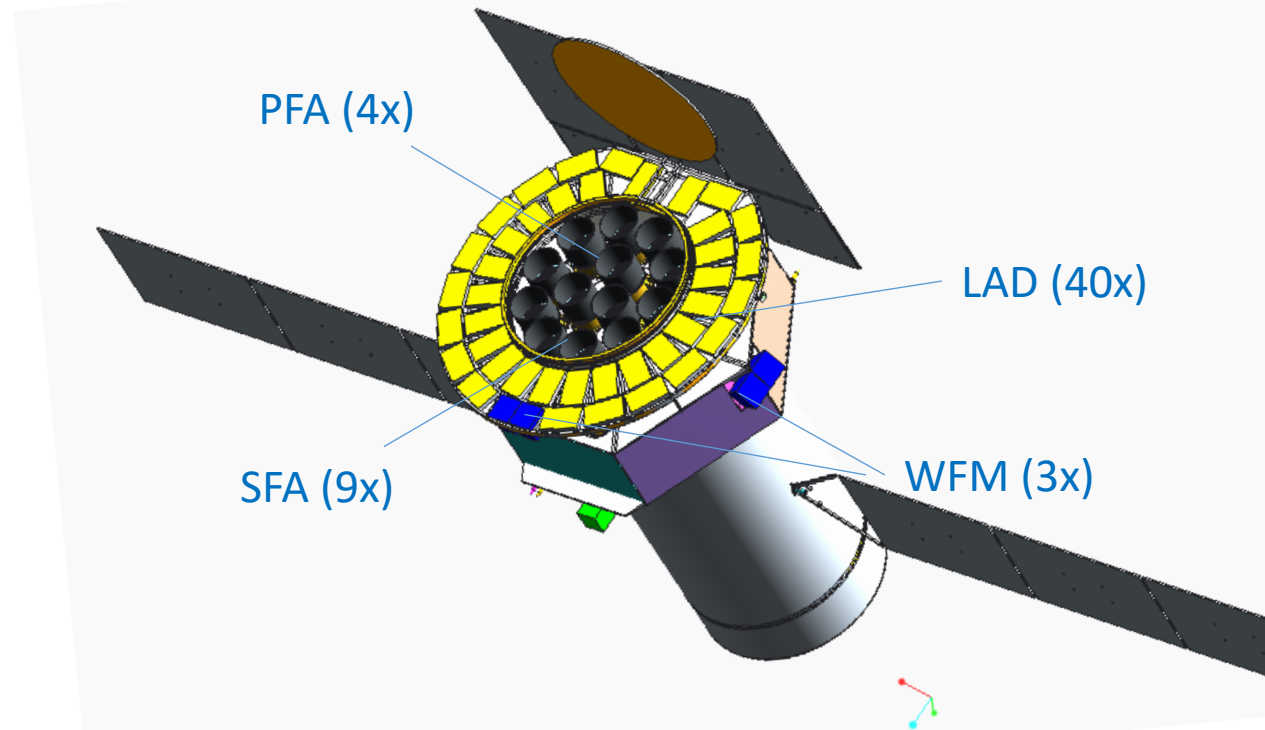
An update activity has started, including multi-messenger astronomy.



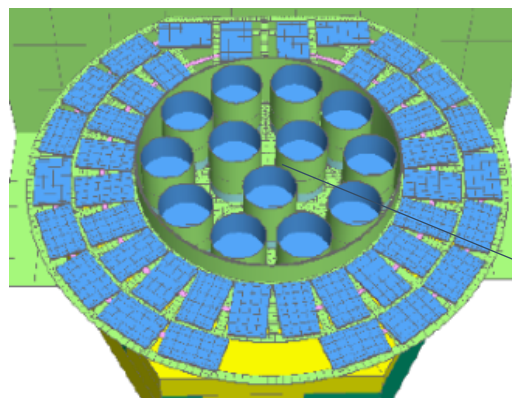
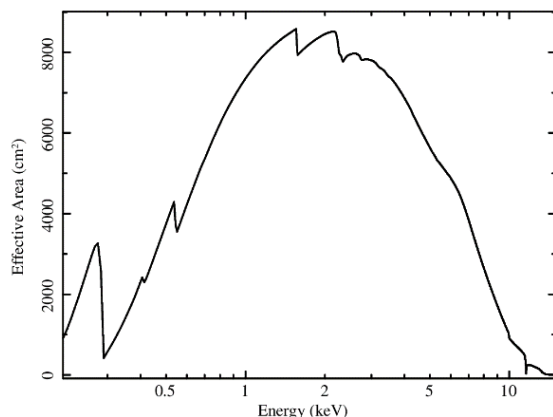
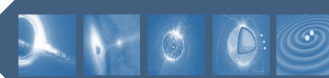


## Payload concept

- Multiple short focal-length modules for large telescope area
- Multiple modules for large-area collimated modules
- Polarimeter with imaging capability
- Wide field monitor







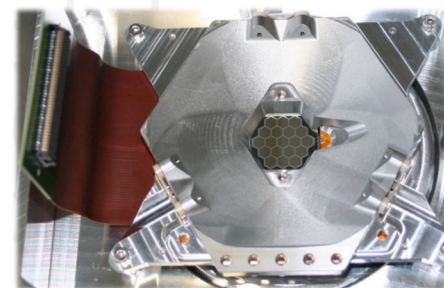
EXTD

COVER

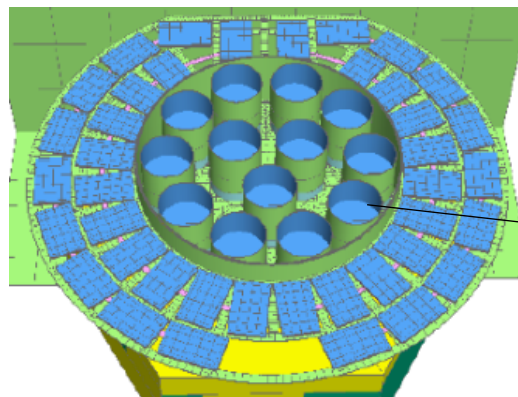
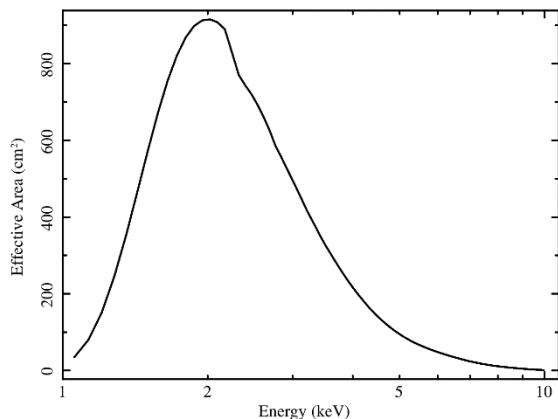
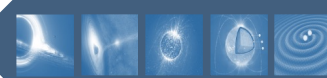
聚焦光学  
X-ray optics



- ❖ Large collecting area achieved by multiple optics with short focal length. Baseline: **9 optics** with 5.25m FL
- ❖ **Total effective area:  $>0.7 \text{ m}^2$  @1 keV,  $0.5 \text{ m}^2$  @6 keV**
- ❖ **Non-imaging**, PSF requirement 1 arcmin HPD, 12' FoV
- ❖ Multi-pixel SDD detector (to enable background subtraction). Single photon,  $<100\mu\text{s}$
- ❖ Energy band: 0.5-10 keV
- ❖ **Energy resolution:  $<180 \text{ eV FWHM}$  @6 keV**



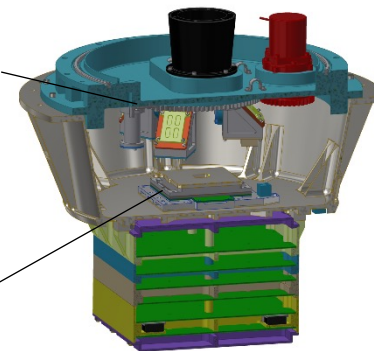
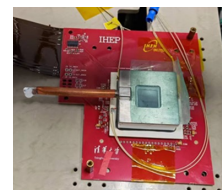
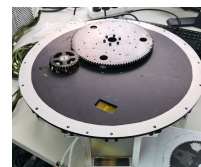
MPE, Germany



COVER

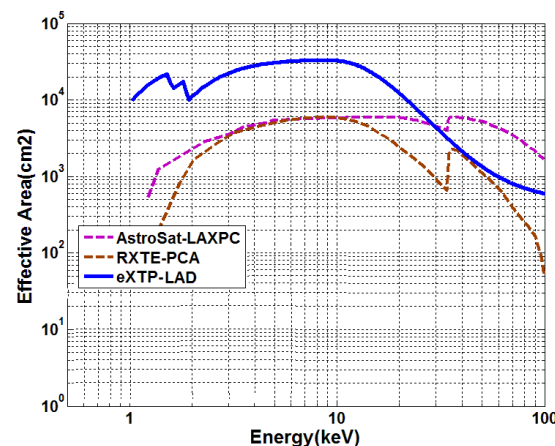
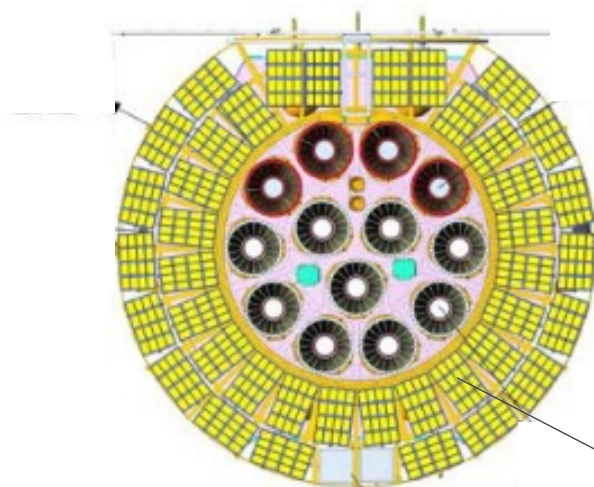
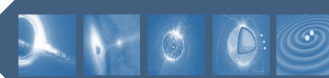
 聚焦光学  
X-ray optics


- ❖ Focal plane **imaging polarimeter**: 4 telescopes with 5.25m FL
- ❖ Imaging, **PSF 20 arcsec** HPD
- ❖ **Total effective area: 900 cm² @2 keV (includes QE)**
- ❖ Gas Pixel Detector: single photon, <100μs
- ❖ Energy band: 2-10 keV
- ❖ Energy resolution: 20% FWHM @6 keV

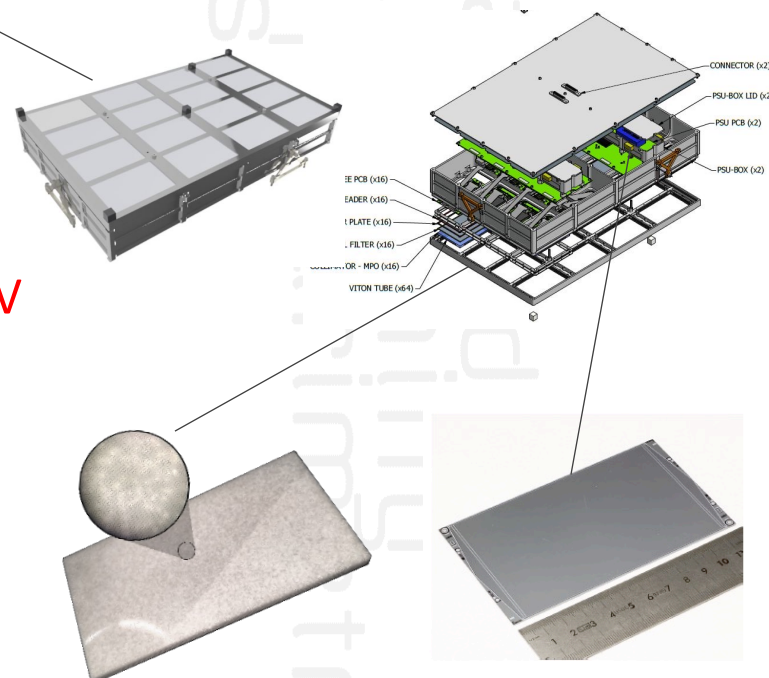


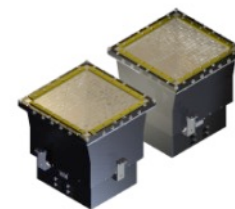
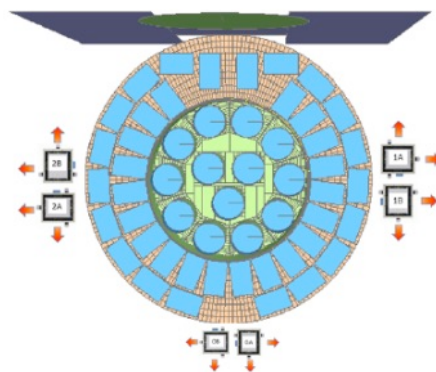
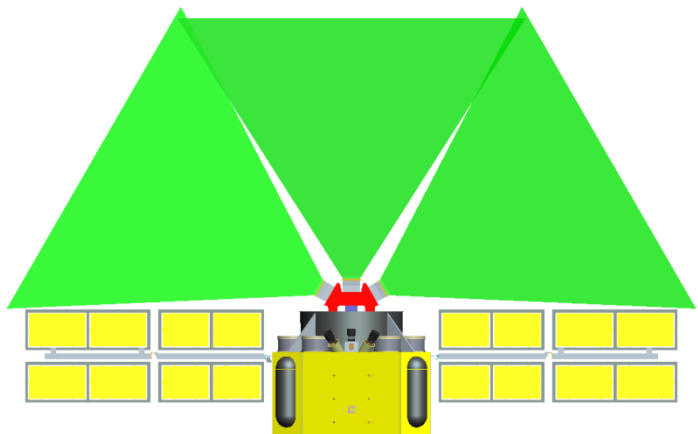
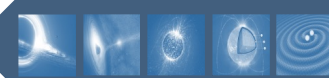
Tsinghua Univ., INFN-Pi



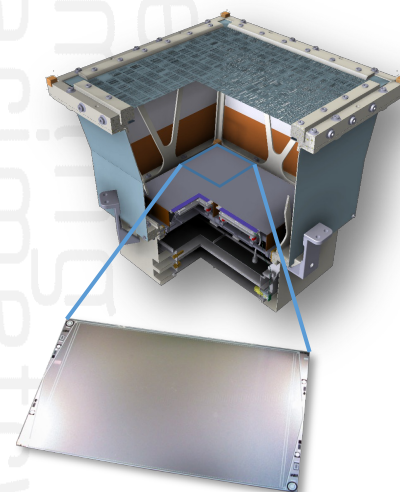


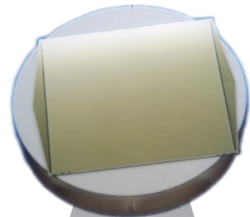
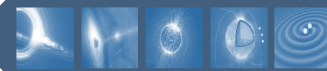
- ❖ Total effective area: 3.0 m<sup>2</sup> @8 keV
- ❖ Energy band: 2-30 keV
- ❖ Energy resolution: <240 eV FWHM @6 keV
- ❖ Based on the LOFT/LAD design
- ❖ 40 Modules on support truss
- ❖ 1° Collimated, large-area SDD detector.  
Single photon, <10μs



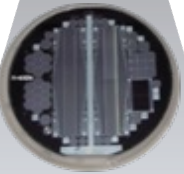


- ❖ Field of View: 4 steradian (at 20% response)
- ❖ Imaging, <5 arcmin angular resolution, 1 arcmin PSFA
- ❖ Energy band: 2-50 keV
- ❖ Energy resolution: 300 eV FWHM @6 keV
- ❖ Effective area: 80 cm<sup>2</sup> @6 keV (1 unit, on axis)
- ❖ Same design as LOFT/WFM, 3 units (6 cameras)
- ❖ Same detectors as LAD (SDD). Single photon, <10μs



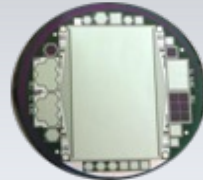


ALICE  
2002



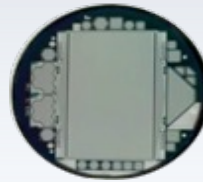
Power,  
Thickness

ALI2  
2010/11



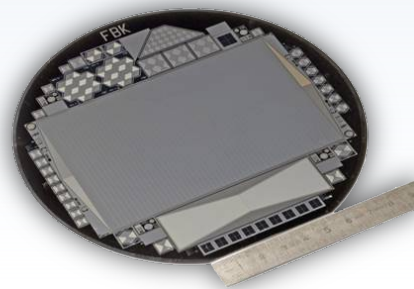
Low-E QE

XDXL1  
2011/12



Pitch

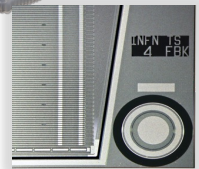
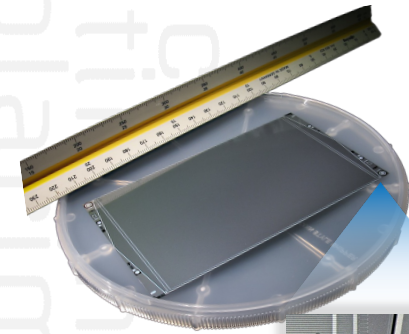
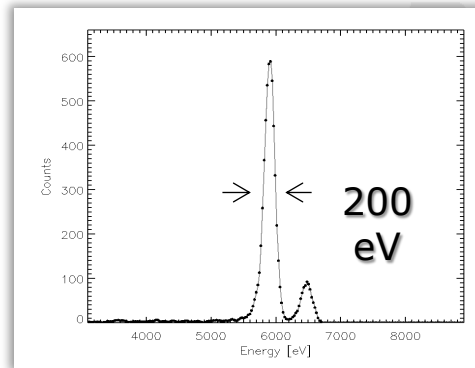
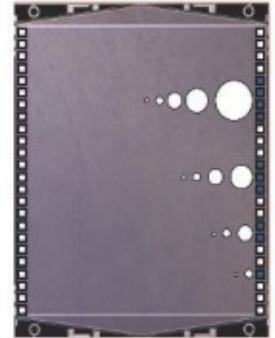
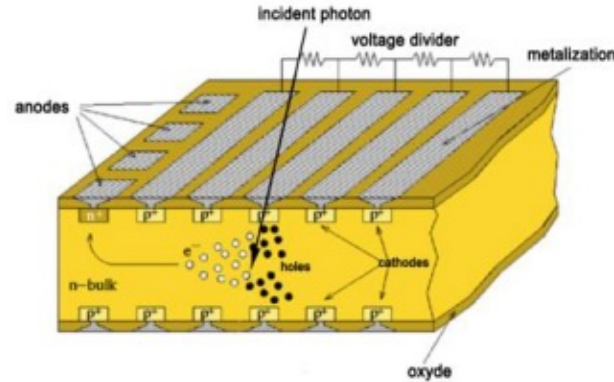
XDXL2  
2012

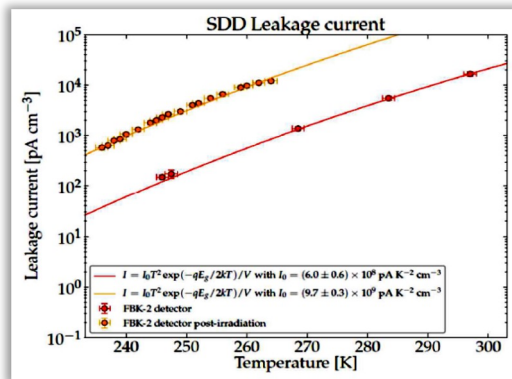
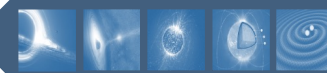


Size

Low- $I_{leak}$

ReDSOX  
2014/17





### NIEL from 11 MeV and 50 MeV protons:

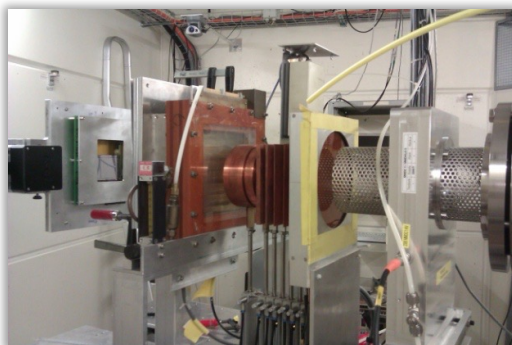
PSI – Zurich

[E. Del Monte et al. 2014, JINST 9]

### NIEL from soft protons (800 keV p+):

Tubingen

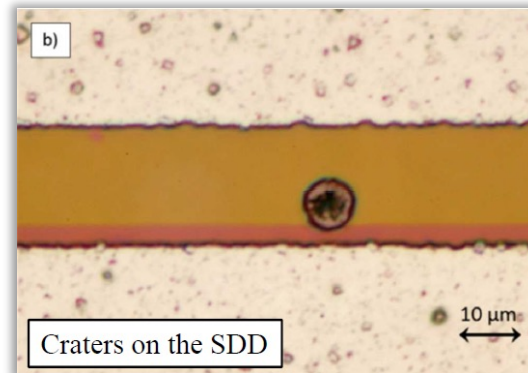
[E. Del Monte et al. 2014, SPIE 9144]



### Variation of the CCE (11 MeV p+):

PSI – Zurich

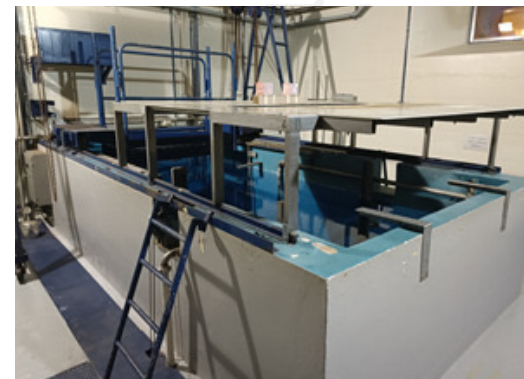
[Del Monte et al. 2015, JINST 10]



### Hypervelocity impacts from debris (0.5-3 mm diameter):

MPIK - Heidelberg

[G. Zampa et al. 2014, JINST 9]

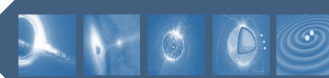


### Total Dose (Co<sup>60</sup> photons, 85 krad):

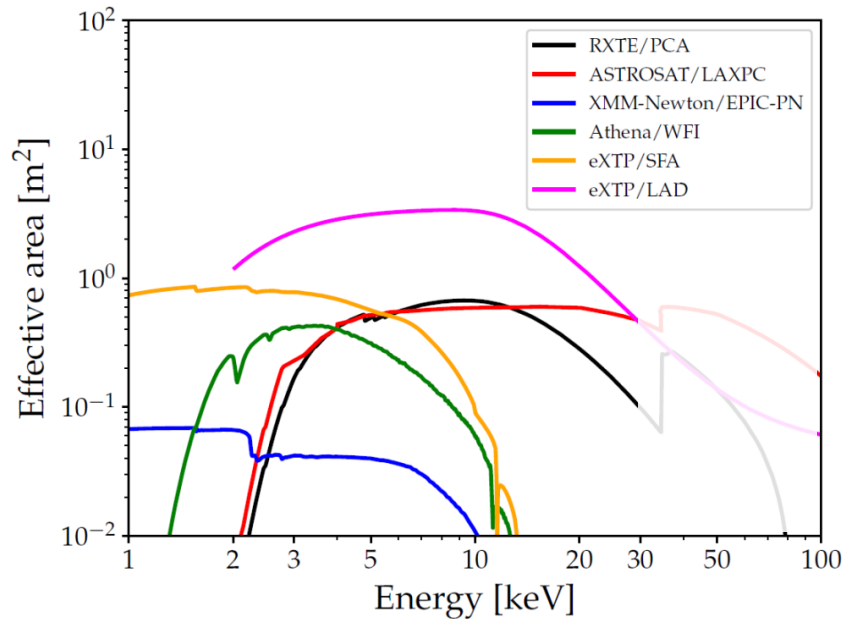
Calliope – Casaccia (Rome)

[F. Ceraudo et al., in preparation]

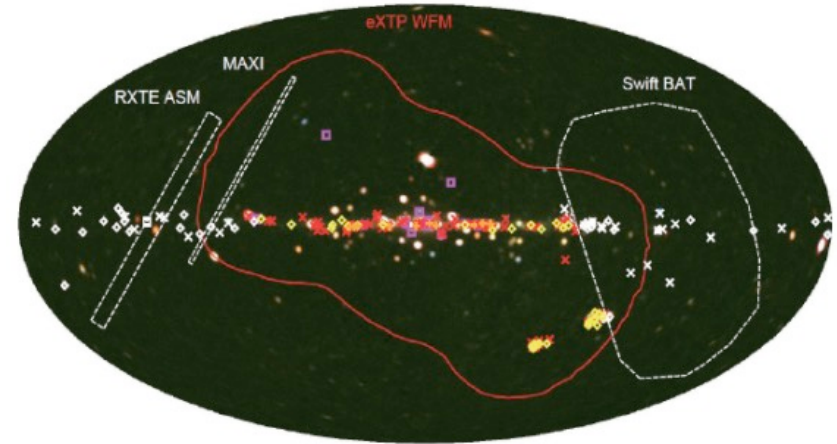




## Effective Area of SFA and LAD

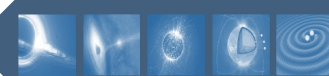


## Instantaneous FoV of WFM



- ❖ **LAD:** 6x RXTE/PCA, 35x XMM-Newton (*but collimated!*) + hard-X response
- ❖ **SFA:** 8x XMM-Newton and 0.3-2x Athena/WFI (*but multiple optics and larger PSF!*). Limiting sensitivity  $\sim 10^{-14}$ - $10^{-15}$  erg cm $^{-2}$  s $^{-1}$
- ❖ **PFA:** 7x IXPE. Sensitivity: 1% MDP in 50ks for a 100 mCrab source
- ❖ **WFM:** Largest FoV ever, first time with 300 eV resolution. 3 mCrab in 50ks





Soft Response

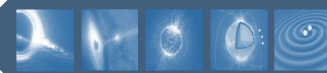
Payload	Parameter	Specification
SFA	Energy range	0.5-10 keV
	Effective area	>7000 cm <sup>2</sup> @1 keV, >5000 cm <sup>2</sup> @6 keV
	Energy resolution	<180 eV FWHM @6 keV
	FoV/HPD	12 arcmin / 1 arcmin
	Focal plane detector	Pixelated SDD (19 pixels)
LAD	Energy range	2-30 keV (extended: 30-80 keV for out-FoV)
	Effective area	30000 cm <sup>2</sup>
	Energy resolution	<240 eV FWHM @6 keV
	FoV	1° (FWHM)
	Detector	Large area SDD (640 units, 40 Modules)
PFA	Energy range	2-10 keV
	Effective area	>900 cm <sup>2</sup> @2 keV (including QE)
	Energy resolution	1.2 keV FWHM @6 keV
	FoV/HPD	12 arcmin / 20 arcsec
	Focal plane detector	GPD (4 units)
WFM	Energy range	2-50 keV
	Energy resolution	300 eV FWHM @6keV
	FoV	>4 sr (at 20% of peak response)
	Angular resolution	<5 arcmin
	Localization accuracy	<1 arcmin
	Detector	Large area SDD

Large area

Polarization

Monitoring





## ❑ Sky visibility

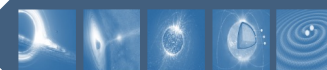
- >50% of the sky accessible by the narrow field instruments at any time (requirement) – current baseline:  $\sim 65\%$  ( $-60^\circ/+30^\circ$ )
- $\frac{1}{4}$  of the sky instantaneously monitored by the WFM at any time

## ❑ Transient events

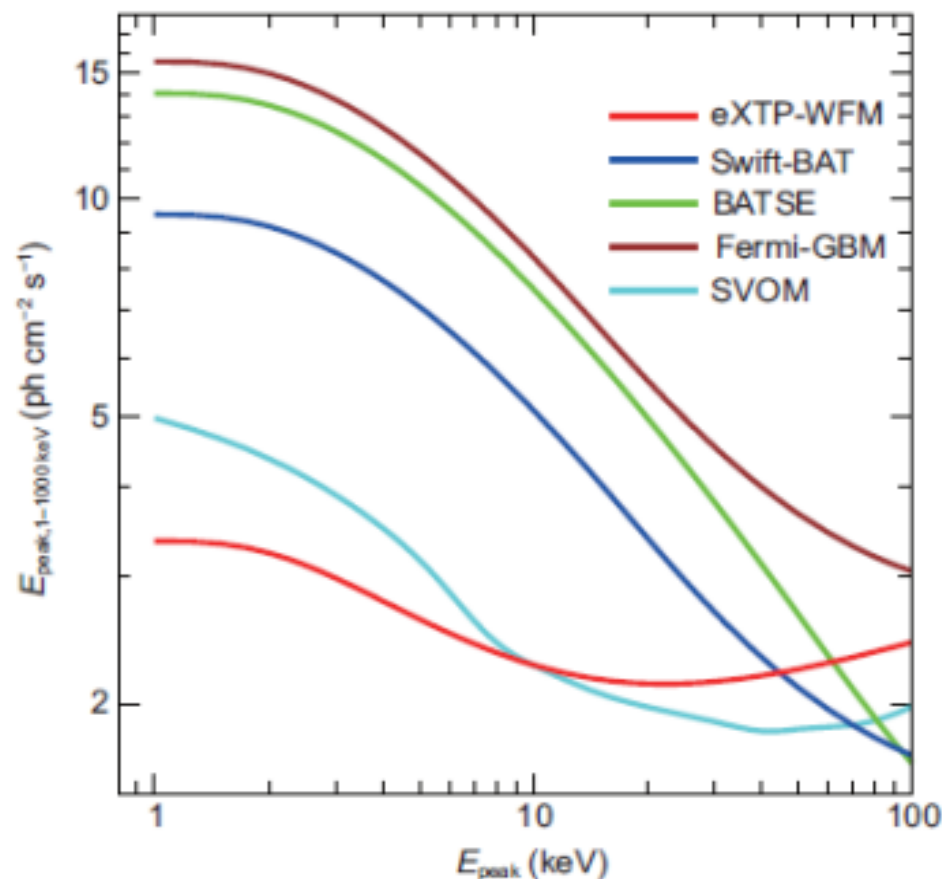
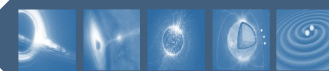
- Onboard triggering and transient localization capability (WFM)
- Autonomous slewing ( $>3^\circ/\text{min}$  minimum speed)
- Transmission of coordinates to the ground: Bei Dou ( $<30\text{s}$  seconds delay)

## ❑ Targets of Opportunity

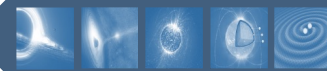
- Large allocation to ToO observations
- Fast uplink of ToO coordinates (Bei Dou)
- $<12$  hours execution time (requirement)



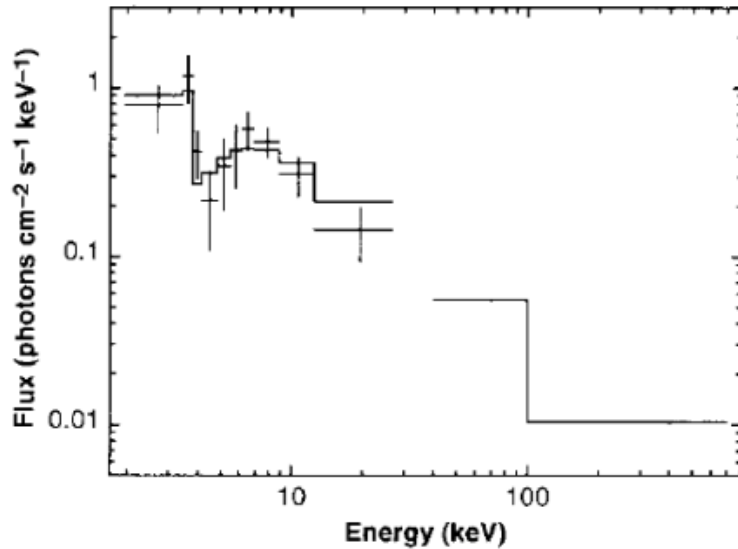
Parameter	Value
Orbit	550 km, $<2.5^\circ$ inclination
Launcher	Long-March CZ-5, from Wenchang
Mass	4500 kg
Power	3.6 kW
Telemetry	1.7 Tb/day (X-band)
Ground Stations	Colombo, Malindi, +
Pointing	3-axis stabilized, $< 0.01^\circ$ (3-sigma)
Sky visibility	50% (goal 75%)
Mission Duration	5 years (goal 8 years)
Launch date	2029



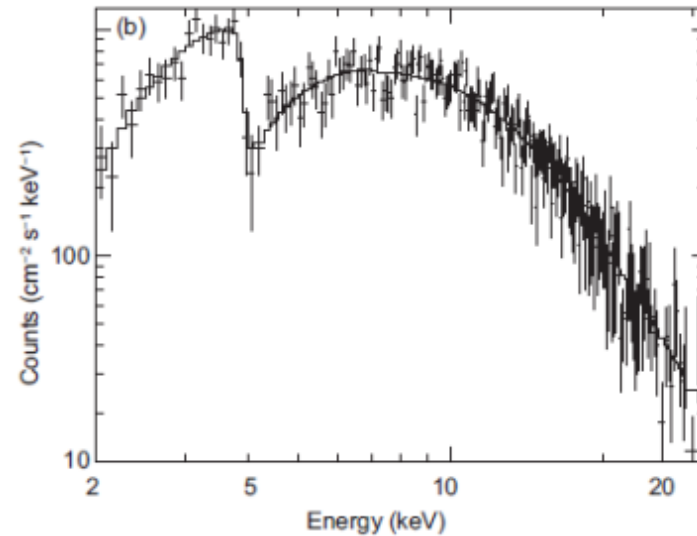
**Figure 17** GRB detection sensitivity in terms of peak flux sensitivity as a function of the spectral peak energy  $E_p$  [359] of the WFM (red) for M4 configuration compared to those of CGRO BATSE (green), Swift BAT (blue), Fermi GBM (brown), and SVOM ECLAIRS (cyan).



BeppoSAX/WFC (Amati et al. 2000)

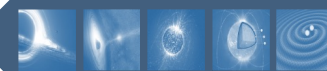


eXTP/WFM

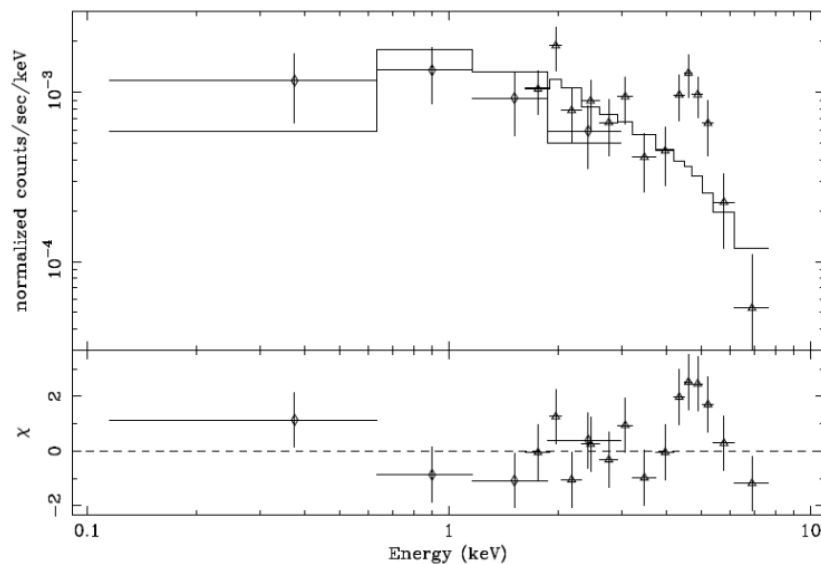


GRB prompt emission, 8s integration, Fe absorption edge at  $z=0.86$

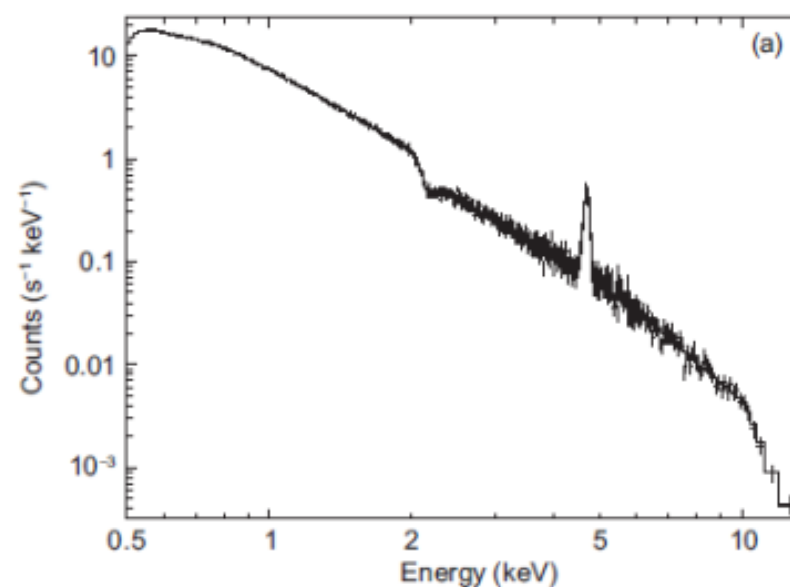




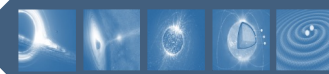
BeppoSAX/NFI (Antonelli et al. 2000)



eXTP/SFA



Afterglow: 12 hours after GRB onset, 50 ks, average flux  $8 \times 10^{-13} \text{ erg cm}^{-2} \text{ s}^{-1}$



eXTP is conceived as a powerful and general observatory for compact Galactic and bright extragalactic objects to date. It will offer for the first time the most complete diagnostics of compact sources: excellent spectral, timing and polarimetry sensitivity on a single payload.

### Five international Science Working Groups

- ❖ Accretion in Strong Field Gravity
- ❖ Dense Matter
- ❖ Strong Magnetism
- ❖ Observatory Science
- ❖ Multi-messenger astronomy

The eXTP Team is open to contributions from the wide scientific community.  
More info at: <http://www.isdc.unige.ch/extp/>