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

MARCO FEROCI

INAF/IAPS & INFN/RM2, ROME, ITALY

ON BEHALF OF THE EXTP CONSORTIUM

- A flagship X-ray observatory mission, being developed by the Chinese Academy of Sciences, with a large contribution by a European Consortium. ESA is studying a MoO participation.

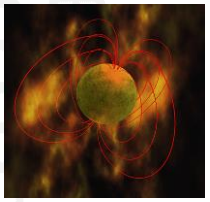
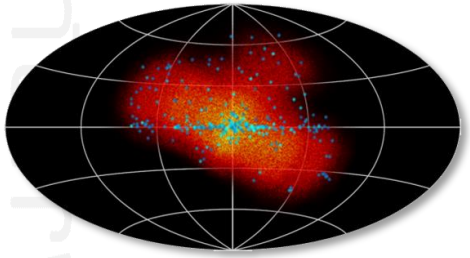
- Currently in Phase B1. The launch date is planned in late 2027, for a minimum mission lifetime of 5 years (goal 8 years).

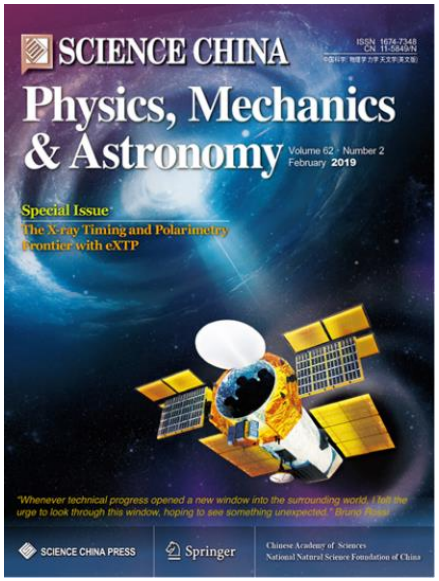
- eXTP is proposed as an observatory open to the worldwide scientific community. It is expected that the eXTP observing plan will be designed based on Core Program observations as well as on a Guest Investigator Program.

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 follow-up.






SCIENCE CHINA
Physics, Mechanics & Astronomy

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

February 2019 Vol. 62 No. 2: 029503
https://doi.org/10.1007/s11433-017-9188-4

**Dense matter with eXTP**

Anna L. Watts[1*], WenFei Yu[2], Juri Poutanen[3,4], Shu Zhang[5], Sudip Bhattacharyya[6], Slavko Bogdanov[7], Long Ji[8], Alessa
Federico Bernardini[12,13], Ig
Deepto Chakrabarty[19], Jérôı
Tiziana Di Salvo[22], Victor Doroshe
Angelo F. Gambino[22], MingYu
Dieter H. Hartmann[29], Kai Hebe
Jean in 't Zand[31], Oleg Kargaltsev
ZhaoSheng Li[38], Manuel Linare
M. Coleman Miller[42], Sl
Chanda Prescod-Weinstein[45], Jin
Andrea Santangelo[8,5], Hendrik Sc
Benjamin Stappers[49], Holger S
Gabriel Török[10], David Tsa
YuPeng Xu[5], Silvia Zane[58],

SCIENCE CHINA
Physics, Mechanics & Astronomy

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

February 2019 Vol. 62 No. 2: 029504
https://doi.org/10.1007/s11433-018-9297-0

**Accretion in strong field gravity with eXTP**

Alessandra De Rosa[1*], Phil Uttley[2], LiJun Gou[3], Yuan Liu[4], Cosimo Bambi[5],

SCIENCE CHINA
Physics, Mechanics & Astronomy

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

February 2019 Vol. 62 No. 2: 029506
https://doi.org/10.1007/s11433-017-9186-1

**Observatory science with eXTP**

Jean J. M. in 't Zand[1*], Enrico Bozzo[2], JinLu Qu[3], Xiang-Dong Li[4], Lorenzo Amati[5], Yang Chen[4], Immacolata Donnarumma[6,7], Victor Doroshenko[8], Stephen A. Drake[9], Margarita Hernanz[10], Peter A. Jenke[11], Thomas
Alessandra De Rosa[7], Elena M
Thomas M. Tauris[19], Joern Wilms
Jean-Luc Atteia[24], Nils A. Ander
Ehud Behar[29], Tomaso Belloni[30], S
João Braga[34], Søren Brandt[3
Edward M. Cackett[39], Riccardo Ca
Frank Chambers[15], Liang Ch
ChiChuan Jin[44], Riccardo Ciol
Zi-Gao Dai[4], Filippo D'Ai
Melania Del Santo[48], Valerio
XiLong Fan[54,55], Robert D. Ferdı
Angelo F. Gambino[51], Poshak Gan
Christian Gouiffès[62], Paola Gra
Craig O. Heinke[65], Jeroen Hor
Peter G. Jonker[1,69], Jordi J
Nobuyuki Kawai[72], Laurens K
Devaky Kunneriath[74], Gan

SCIENCE CHINA
Physics, Mechanics & Astronomy

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

February 2019 Vol. 62 No. 2: 029505
https://doi.org/10.1007/s11433-018-9234-3

**Physics and astrophysics of strong magnetic field systems with eXTP**

Andrea Santangelo[1,2*], Silvia Zane[3*], Hua Feng[4*], RenXin Xu[5*], Victor Doroshenko[1*], Enrico Bozzo[6], Ilaria Caiazzo[9], Franc
Daniela Huppenl
Nanda Rea[16,1
Cristina Baglio[25], I
Ersin Göğüş[32], Can
Romana Miku
Andrea Tie

SCIENCE CHINA
Physics, Mechanics & Astronomy

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

February 2019 Vol. 62 No. 2: 029502
https://doi.org/10.1007/s11433-018-9309-2

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

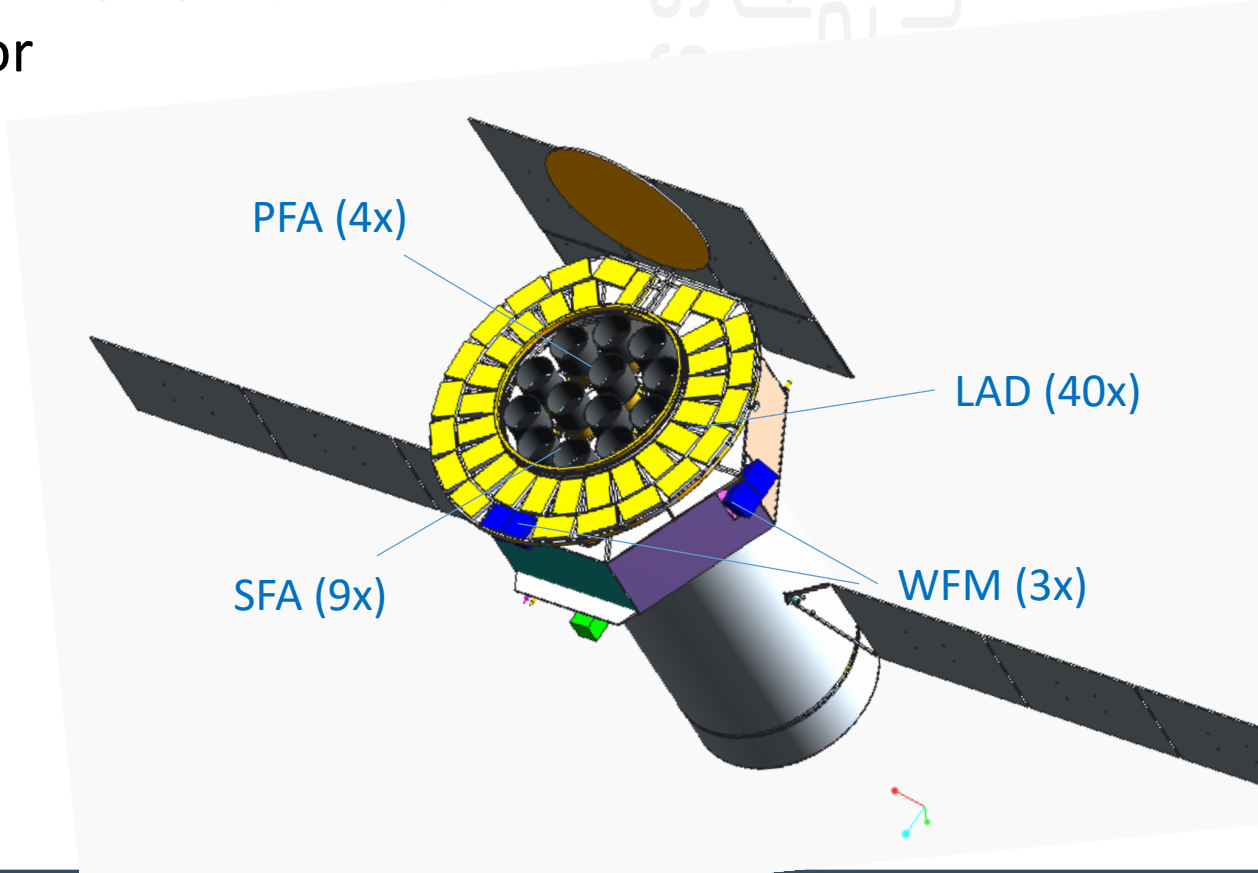
ShuangNan Zhang[1*], Andrea Santangelo[1,2*], Marco Feroci[3,4*], YuPeng Xu[1*], FangJun Lu[1], Yong Chen[1], Hua Feng[5], Shu Zhang[1], Søren Brandt[36], Margarita Hernanz[12,13], Luca Baldini[33], Enrico Bozzo[6], Riccardo Campana[23], Alessandra De Rosa[3], YongWei Dong[1], Yuri Evangelista[3,4], Vladimir Karas[8], Norbert Meidinger[16], Aline Meuris[10], Kirpal Nandra[16], Teng Pan[21], Giovanni Pareschi[31], Piotr Orleanski[37], QiuShi Huang[22], Stephane Schanne[10], Giorgia Sironi[31], Daniele Spiga[31], Jiri Svoboda[8], Gianpiero Tagliaferri[31], Christoph Tenzer[2], Andrea Vacchi[25,26], Silvia Zane[14],

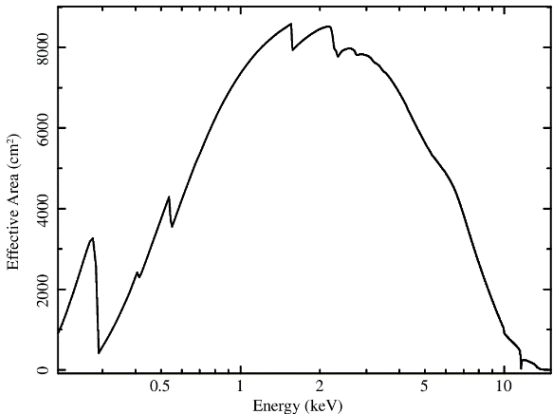
## 2019 White Papers for eXTP science case and mission:

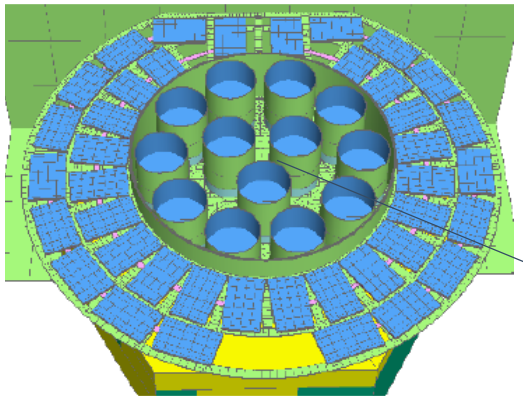
- Dense Matter
- Strong Field Gravity
- Strong Magnetism
- Observatory Science
- Instrument and mission

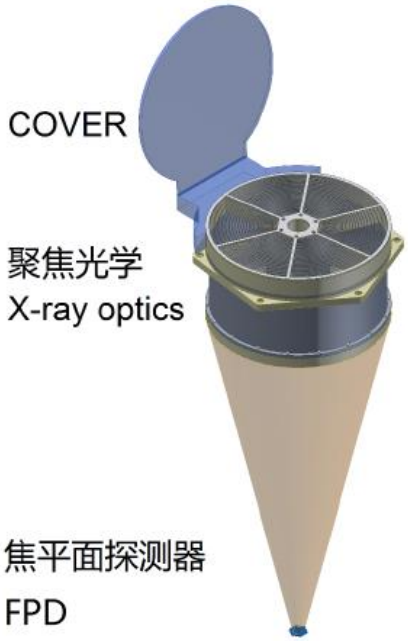
# Payload concept

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

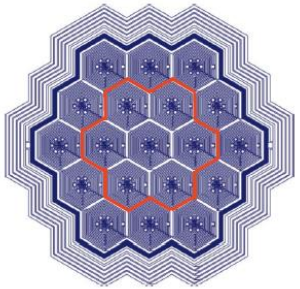


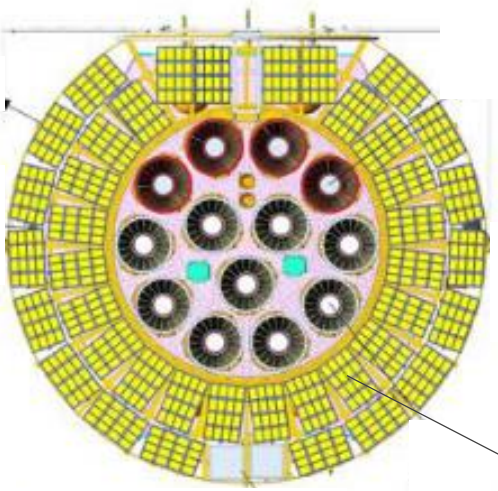


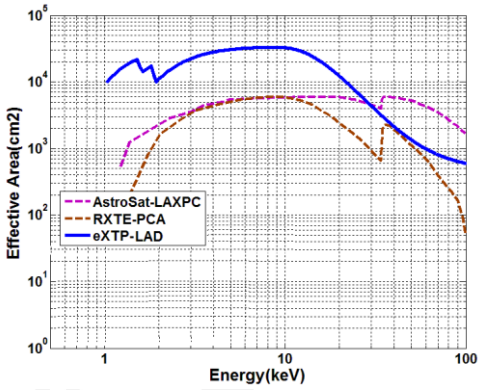



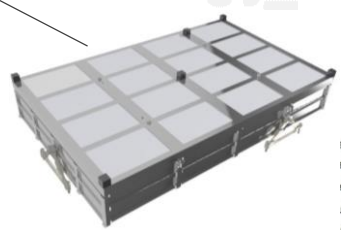


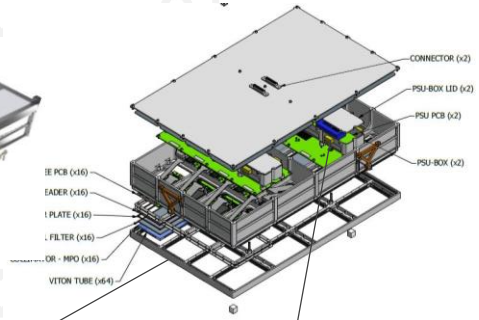

- Large collecting area achieved by multiple optics with short focal length. Baseline: 9 optics with 5.25m FL
- Total effective area: >0.7 $m^2$ @1 keV, 0.5 $m^2$ @6 keV
- Non-imaging, PSF requirement 1 arcmin HPD, 12’ FoV
- Multi-pixel SDD detector (to enable background subtraction). Single photon,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

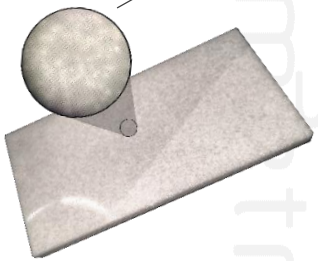


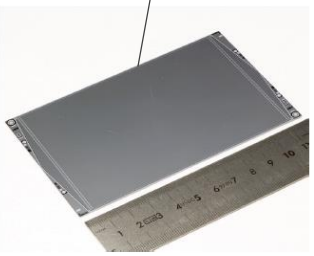




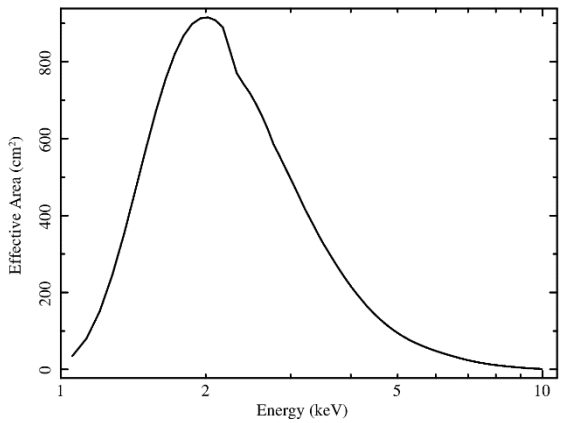



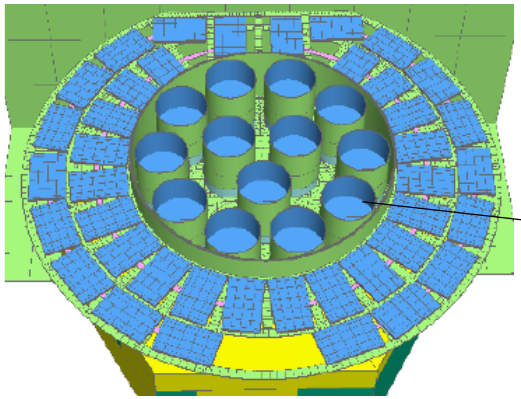


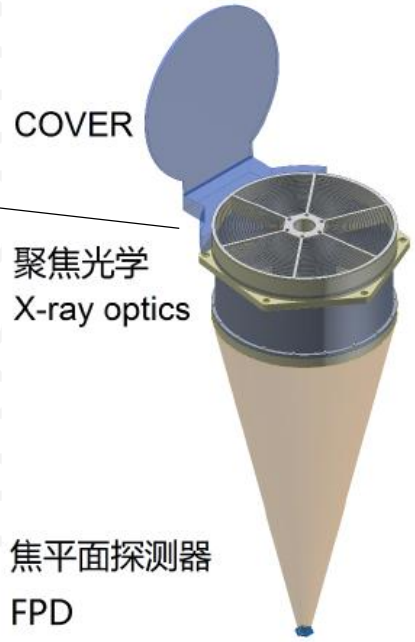





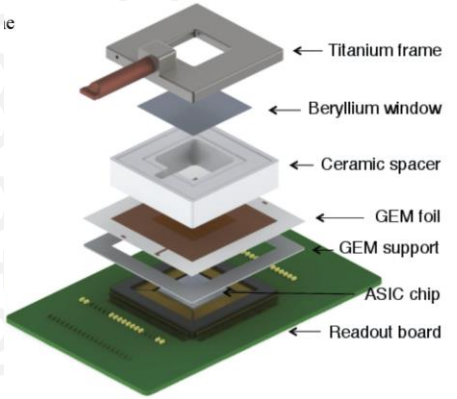
- Total effective area: 3.4 $m^2$ @8 keV
- Energy band: 2-30 keV
- Energy resolution: <240 eV FWHM @6 keV
- Based on the LOFT/LAD design
- 40 Modules on support structure
- 1° Collimated, large-area SDD detector.
  Single photon, <10µs

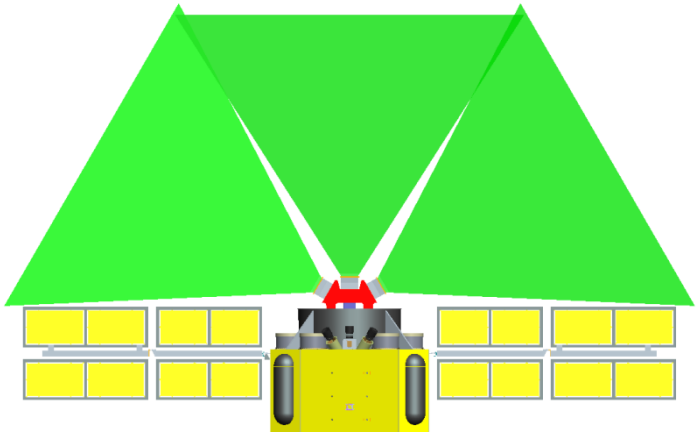


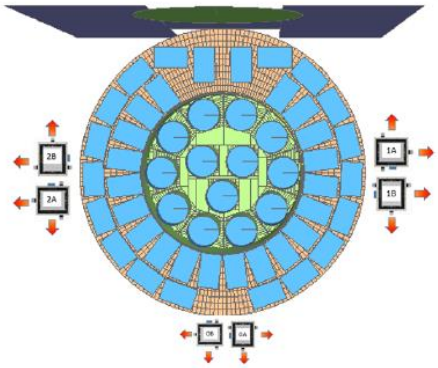



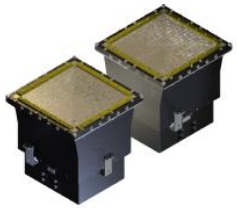



- Focal plane imaging polarimeter: 4 telescopes with 5.25m FL
- Imaging, PSF 20 arcsec HPD
- Total effective area: 900 $cm^2$ @2 keV (includes QE)
- Gas Pixel Detector: single photon, <100µs
- Energy band: 2-10 keV
- Energy resolution: 20% FWHM @6 keV

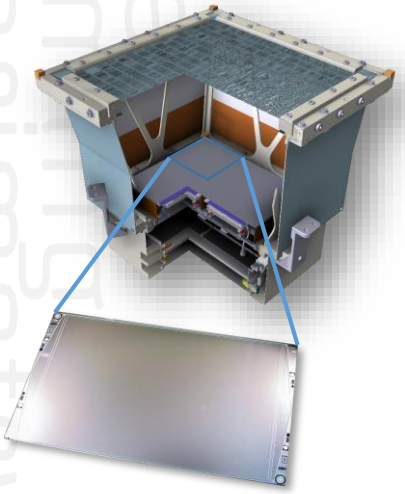




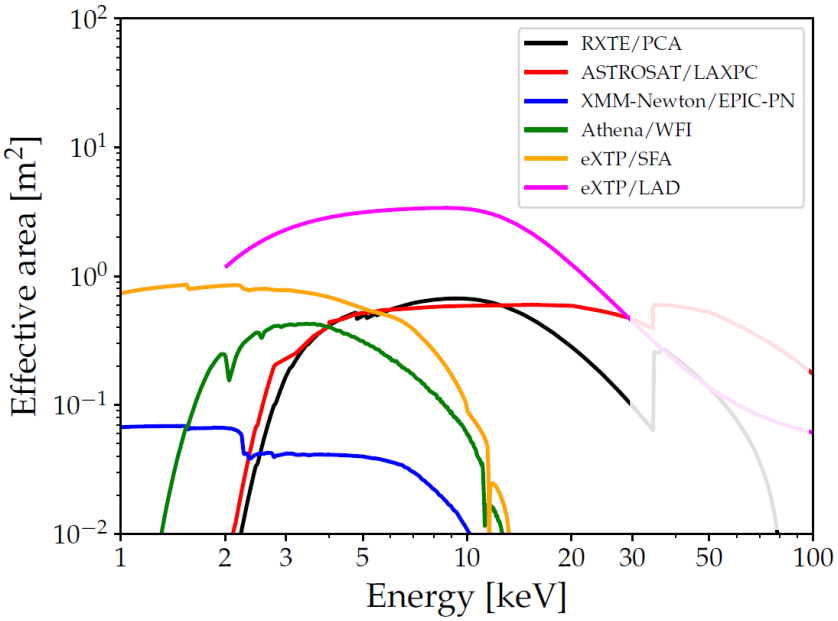




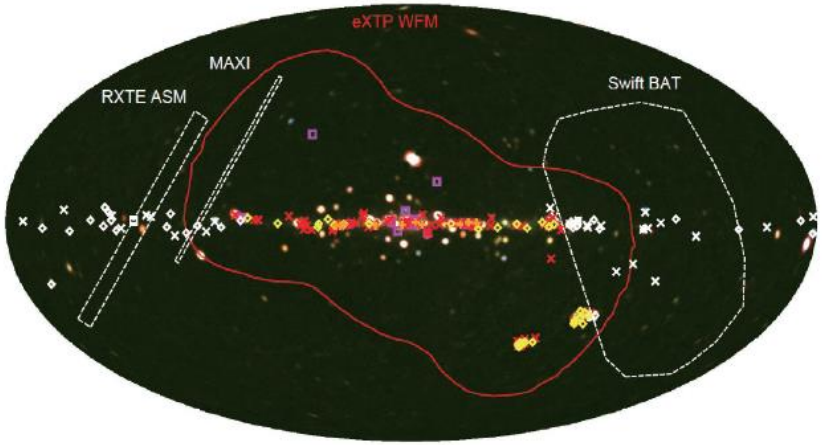
- Field of View: 4 steradian (at 20% response)
- Imaging, <5 arcmin angular resolution, 1 arcmin PSLA
- Energy band: 2-50 keV
- Energy resolution: 300 eV FWHM @6 keV
- Effective area: 80 $cm^2$ @6 keV (1 unit, on axis)
- 3 units (6 cameras)
- Same detectors as LAD (SDD). Single photon, <10μs



## 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 (*but multiple optics and larger PSF*!).
  Limiting sensitivity ~$10^{-14}$-$10^{-15}$ erg cm$^{-2}$ s$^{-1}$
- ❖ **PFA**: 5x 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

| Payload | Parameter | Specification |
|---|---|---|
| SFA (Soft Response) | Energy range | 0.5-10 keV |
| | Effective area | >7000 $cm^2$ @1 keV, >5000 $cm^2$ @6 keV |
| | Energy resolution | <180 eV FWHM @6 keV |
| | FoV/HPD | 12 arcmin / 1 arcmin |
| | Focal plane detector | Pixelated SDD (19 pixels) |
| LAD (Large area) | Energy range | 2-30 keV (extended: 30-80 keV for out-FoV) |
| | Effective area | 34000 $cm^2$ |
| | Energy resolution | <240 eV FWHM @6 keV |
| | FoV | 1° (FWHM) |
| | Detector | Large area SDD (640 units, 40 Modules) |
| PFA (Polarization) | Energy range | 2-10 keV |
| | Effective area | >900 $cm^2$ @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 (Monitoring) | 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 |

## Sky visibility

- >50% of the sky accessible by the narrow field instruments at any time (requirement) – current baseline: ~65% (-60°/+30°)
- ¼ of the sky instantaneously monitored by the WFM at any time

## Transient events

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

## Targets of Opportunity

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

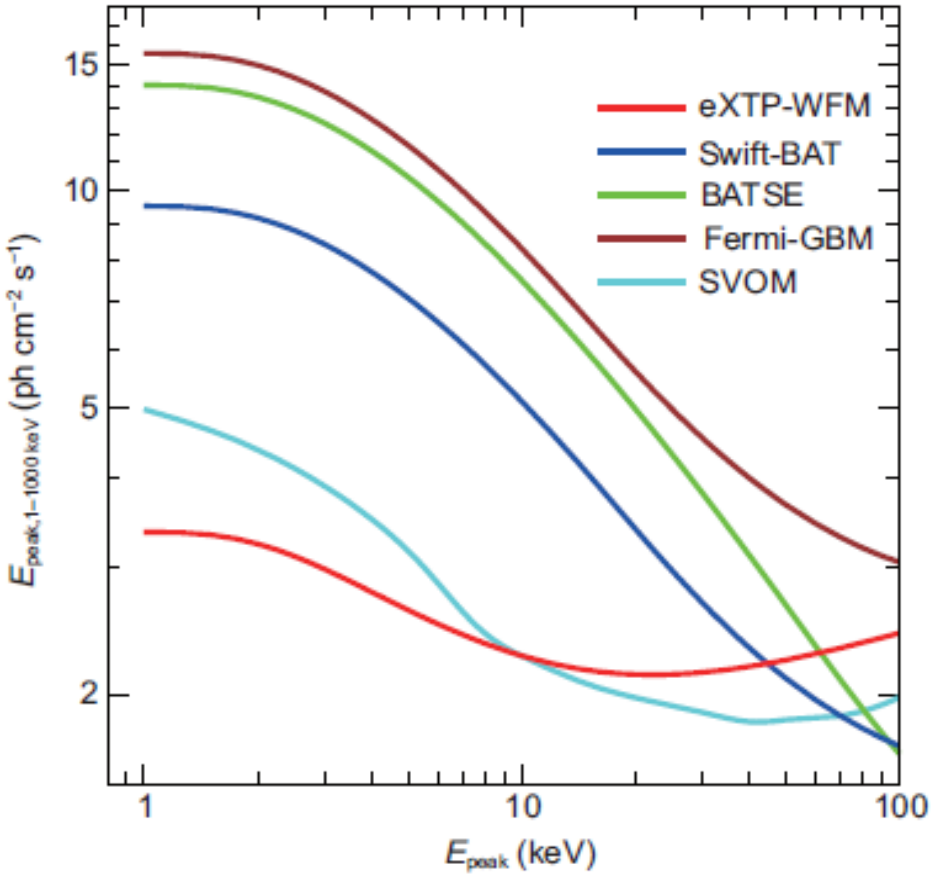
| Parameter | Value |
|---|---|
| Orbit | 550 km, <2.5° inclination |
| Launcher | Long-March CZ-5, from Wenchang |
| Mass | 4500 kg |
| Power | 3.6 kW |
| Telemetry | 1.7 Tb/day (X-band) |
| Ground Stations | Colombo, Malindi, + |
| Pointing | 3-axis stabilized, < 0.01° (3-sigma) |
| Sky visibility | 50% (goal 75%) |
| Mission Duration | 5 years (goal 8 years) |
| Launch date | 2027 |

## eXTP PI Institute: IHEP/CAS, Beijing

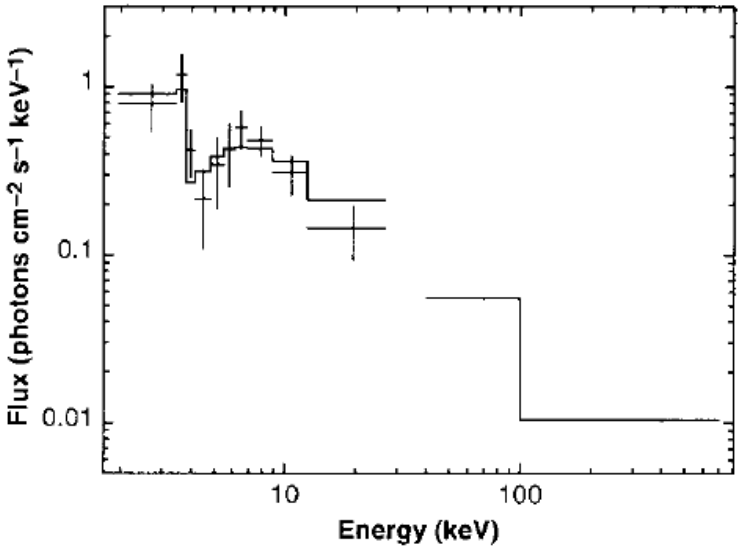
- CAS — Chinese Academy of Sciences
- CNSA
- IHEP Beijing — Institute of High Energy Physics, Chinese Academy of Sciences
- Tsinghua University
- Tongji University — Tongji University
- CAST Beijing — 中国空间技术研究院, China Academy of Space Technology
- IAMC Shanghai — microsat

- Italy — INAF, INFN, Fondazione Bruno Kessler, Politecnico di Milano
- Spain — CSIC, IEEC
- Germany — Eberhard Karls Universität Tübingen, MPE, FAU Friedrich-Alexander Universität Erlangen-Nürnberg
- France — cea
- Switzerland — Université de Genève
- Czech Republic — Astronomical Institute of the Czech Academy of Sciences
- Poland — CBK PAN, CAMK PAN
- Denmark — DTU
- The Netherlands — NOVA, SRON
- Austria — universität wien
- Turkey — Sabancı Üniversitesi, TÜBİTAK

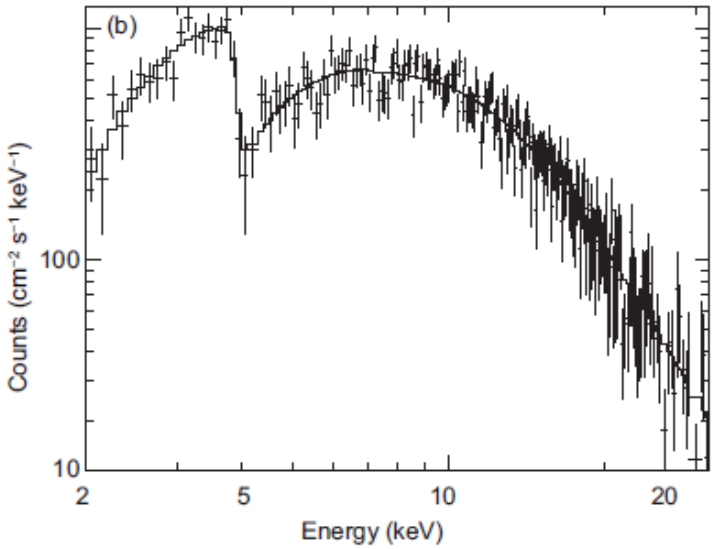
- **Observatory Type -** eXTP is designed as an Observatory. The science program will include a Core Program and a Guest Observer Program. All data should become public after the proprietary period. Some data may go public immediately.
- **European MS and China** - The share between European MS and China will be defined at agency level at a later stage (MoU). The science return is expected to be proportional to the contribution to the mission.
- **ESA** - The potential ESA contribution to the mission is expected to be parallel to that of the individual Member States. It will give science access to a fraction of the observing time / data proportional to the contribution. This fraction will likely add on top of the science return to the individual MS.


15
10
5
2
1
10
100
$E_{peak,1-1000\,keV}$ (ph cm$^{-2}$ s$^{-1}$)
$E_{peak}$ (keV)
eXTP-WFM
Swift-BAT
BATSE
Fermi-GBM
SVOM

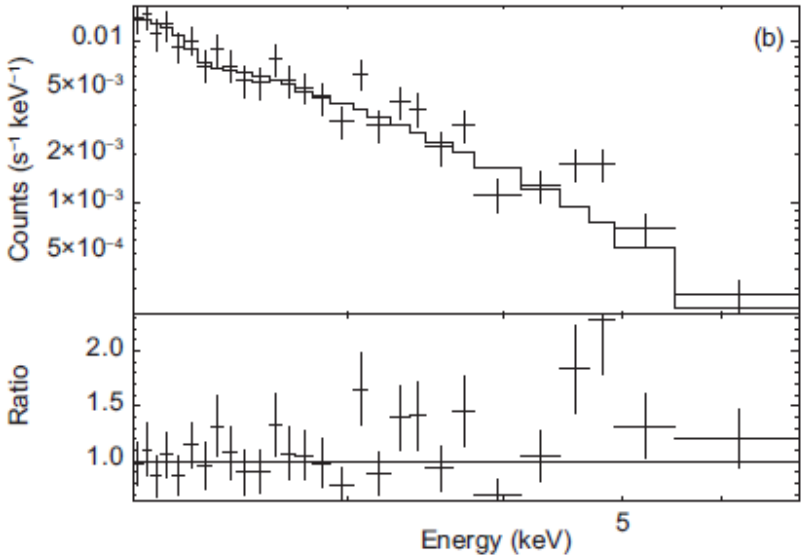
BeppoSAX/WFC (Amati et al.)



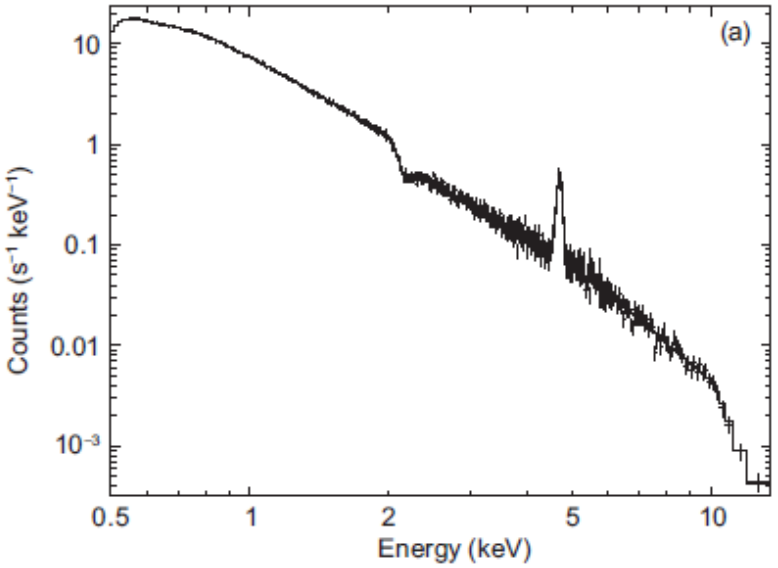

eXTP/WFM



Swift/XRT




eXTP/SFA



- Large instantaneous field of view of WFM
- Low-energy response and spectral resolution on prompt emission
- Onboard triggering, localization and real-time broadcasting
- Autonomous slew of the spacecraft
- High-throughput (~$m^2$), spectral observations of early afterglow
- X-ray polarimetry of early afterglow

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.

**Four international Science Working Groups**
(see, e.g., http://www.isdc.unige.ch/extp/ ):

- Accretion in Strong Field Gravity
- Dense Matter
- Strong Magnetism
- Observatory Science

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

References for the eXTP science and mission: special issue on

**Science China, Volume 62, Issue 2, February 2019**