The enhanced X-ray Timing and Polarimetry Mission

Marco Feroci

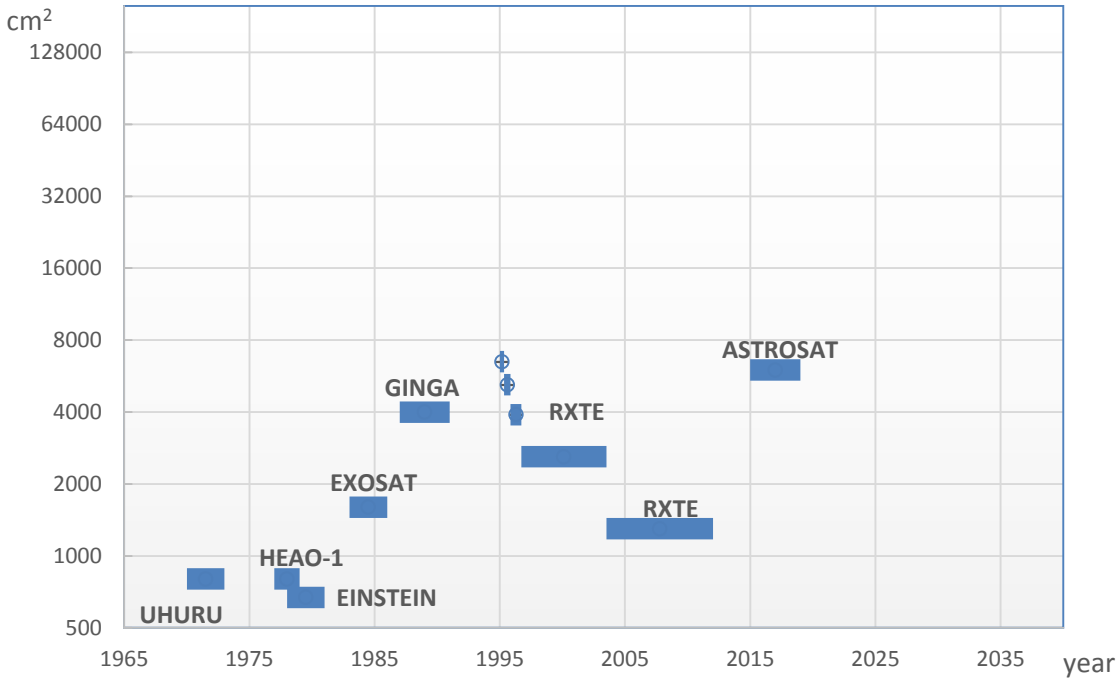
INAF & INFN, Rome

Shuang-Nan Zhang

IHEP, CAS, Beijing

A short history of Timing in time

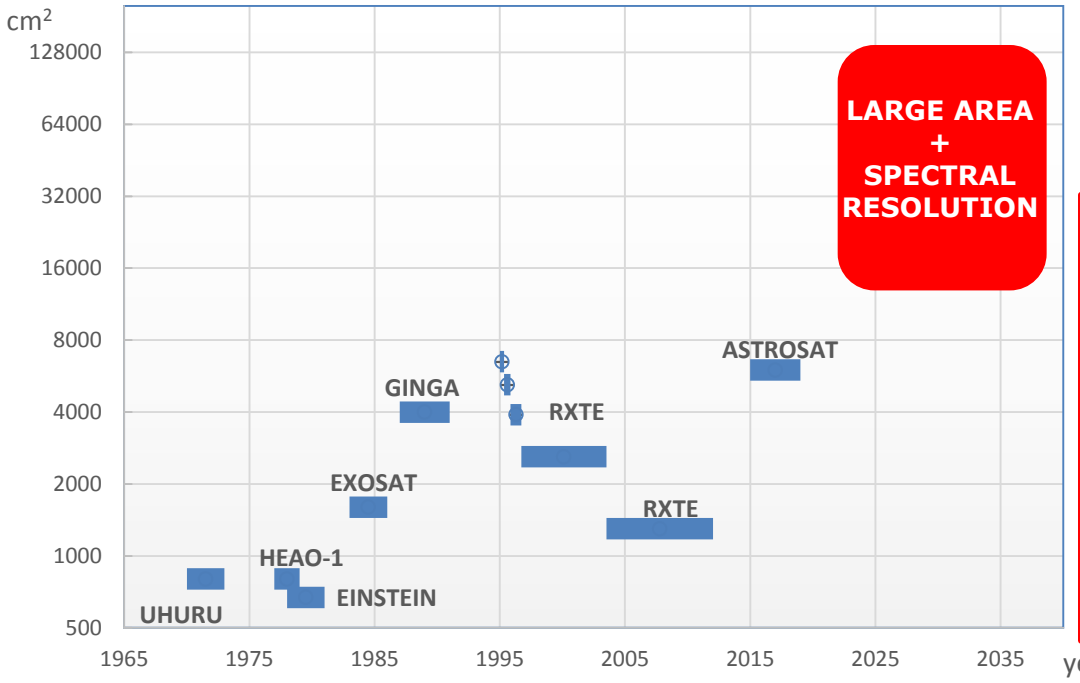
UHURU	1970-1973, 800 cm^2, X-ray sky, accreting X-ray pulsars
HEAO-1	1977-1979, A2: 400-800 cm^2, variability and eclipses
EINSTEIN	1978-1981, MPC: 670 cm^2, extend number of known sources
EXOSAT	1983-1986, ME: 1600 cm^2, QPOs in LMXB
GINGA	1987-1991, LAC: 4000 cm^2, transient BHCs
RossiXTE	1995-2012, PCA: 2000-6000 cm^2, kHz QPOs, fast BH QPOs, AMXP
ASTROSAT	2015- : LAXPC: 6000 cm^2 at 6 keV



TIMING
Proportional Counters,
1.2 keV FWHM @ 6 keV

A short history of Timing in time

UHURU	1970-1973, 800 cm^2, X-ray sky, accreting X-ray pulsars
HEAO-1	1977-1979, A2: 400-800 cm^2, variability and eclipses
EINSTEIN	1978-1981, MPC: 670 cm^2, extend number of known sources
EXOSAT	1983-1986, ME: 1600 cm^2, QPOs in LMXB
GINGA	1987-1991, LAC: 4000 cm^2, transient BHCs
RossiXTE	1995-2012, PCA: 2000-6000 cm^2, kHz QPOs, fast BH QPOs, AMXPs
ASTROSAT	2015- : LAXPC: 6000 cm^2 at 6 keV



TIMING
Proportional Counters,
1.2 keV FWHM @ 6 keV

LARGE-AREA SPECTRAL-TIMING

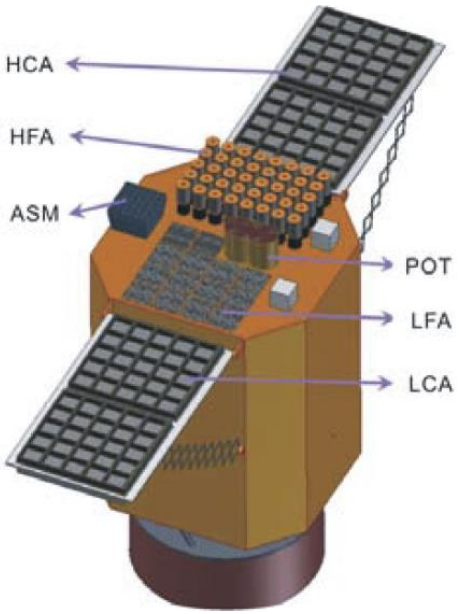
ACCESS TO:

- **Properties of ultradense matter (EoS in neutron stars)**
- **Matter under strong field gravity (e.g., tests of General Relativity)**

XTP
X-ray Timing and Polarimetry

- Mission of the Chinese Academy of Sciences
- Selected in 2011 as one of 8 «Background missions»
- Phase A study by IHEP in 2011-2014

XTP 2012



Science drivers:

Strong Field Gravity

Ultradense matter

Strong Magnetism

Payload:

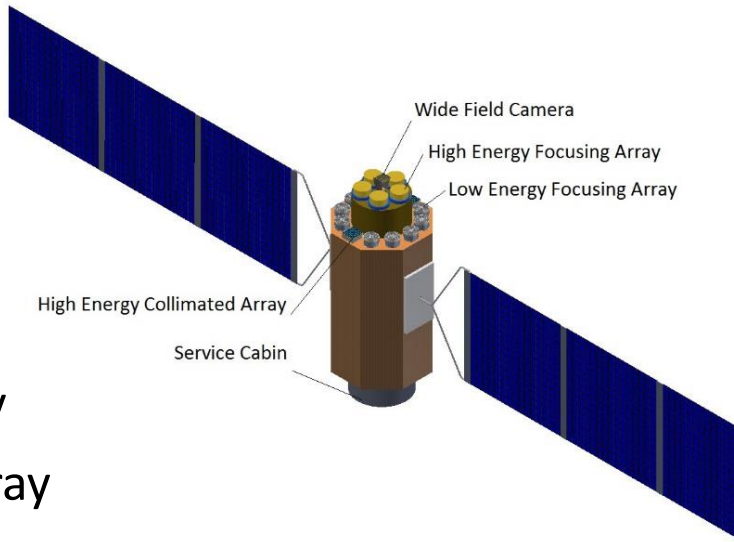
Low Energy Focusing Array

High Energy Focusing Array

High Energy Collimated Array

Wide Field Camera

XTP 2013



LOFT

Large Observatory For x-ray Timing

- Mission proposed to the European Space Agency
- Selected in 2011 by ESA as one of 4 M3 candidate mission in Cosmic Vision
- Phase A study by ESA and LOFT Consortium in 2011-2014
- Eventually not selected as final M3 mission

Science Drivers:

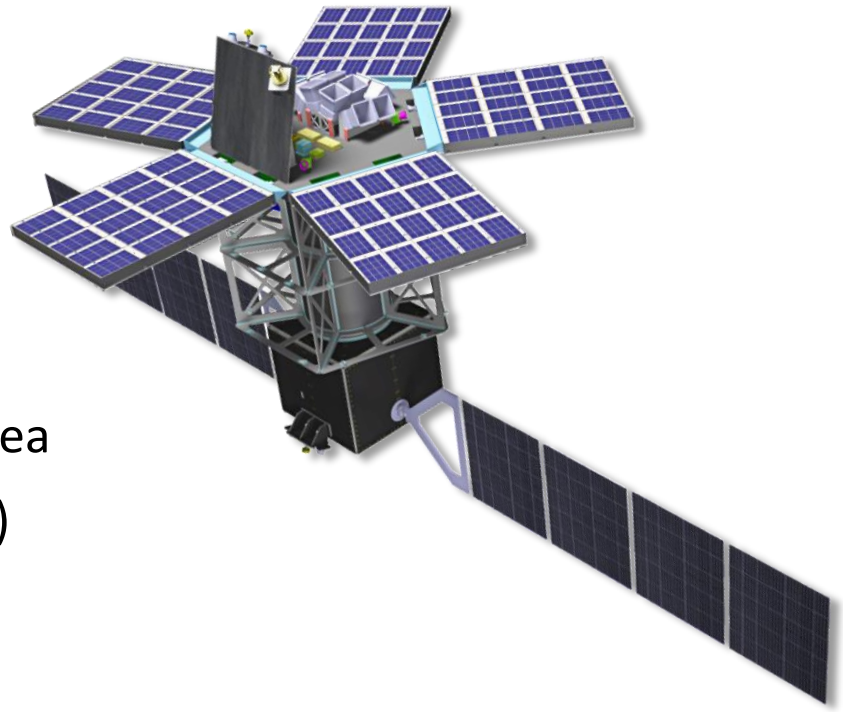
Strong Field Gravity

Ultradense matter

Payload:

Large Area Detector – 10 m^2 effective area

Wide Field Monitor – 5 units (5.5 sr FoV)



eXTP
enhanced X-ray Timing and Polarimetry

- LOFT-XTP collaboration started in 2013 and developed for the (unsuccessful) LOFT-M4 proposal
- LOFT-XTP payload design merged: eXTP
- CAS Phase A study of eXTP in 2014-2015, in collaboration with the European team

Payload:

Spectroscopy Focusing Array – 0.9 m^2 @1 keV

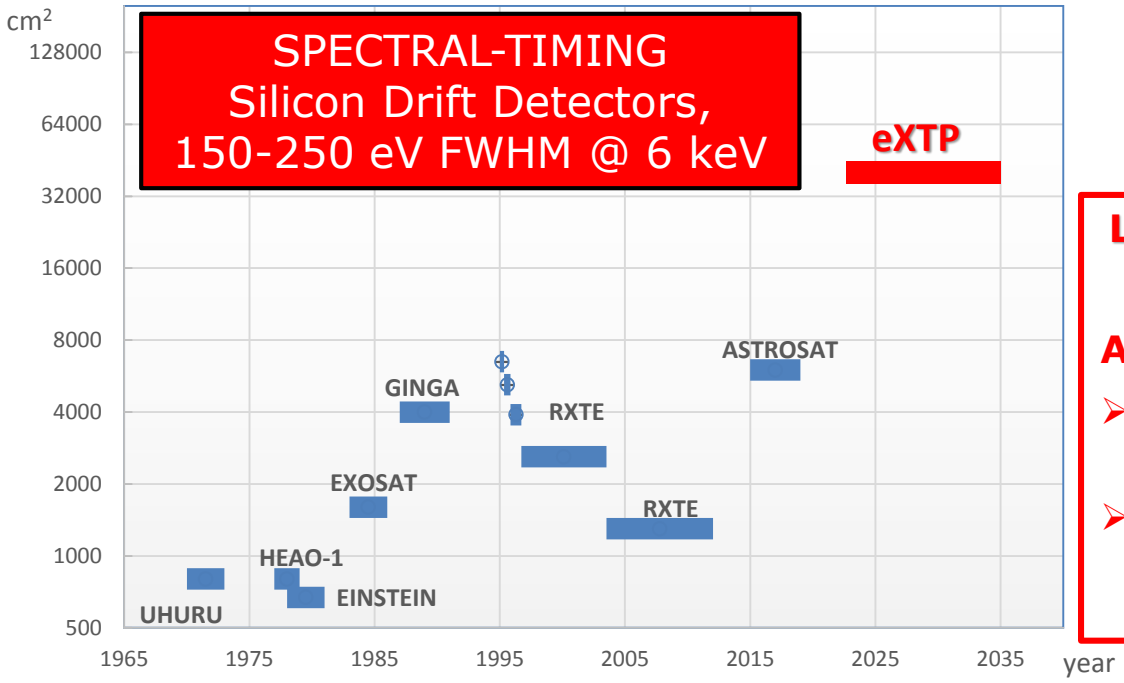
Large Area Detector – 3.4 m^2 @8 keV

Polarimetry Focusing Array – 240 cm^2 at 6 keV

Wide Field Monitor – 3 units (4 sr FoV)

A short history of Timing in time

UHURU	1970-1973, 800 cm^2, X-ray sky, accreting X-ray pulsars
HEAO-1	1977-1979, A2: 400-800 cm^2, variability and eclipses
EINSTEIN	1978-1981, MPC: 670 cm^2, extend number of known sources
EXOSAT	1983-1986, ME: 1600 cm^2, QPOs in LMXB
GINGA	1987-1991, LAC: 4000 cm^2, transient BHCs
RossiXTE	1995-2012, PCA: 2000-6000 cm^2, kHz QPOs, fast BH QPOs, AMXPs
ASTROSAT	2015- : LAXPC: 6000 cm^2 at 6 keV



TIMING
Proportional Counters,
1.2 keV FWHM @ 6 keV

LARGE-AREA SPECTRAL-TIMING

ACCESS TO:

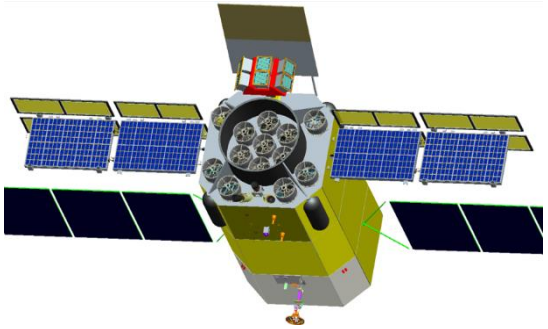
- **Properties of ultradense matter (EoS in neutron stars)**
- **Matter under strong field gravity (e.g., tests of General Relativity)**

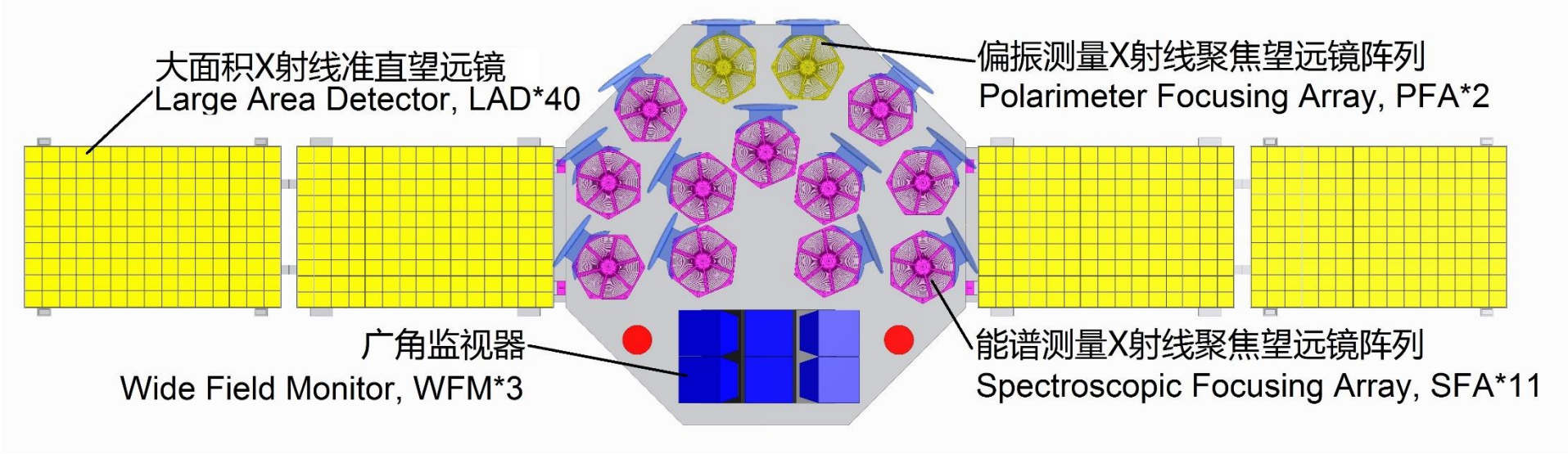
eXTP

enhanced X-ray Timing and Polarimetry

Payload concept

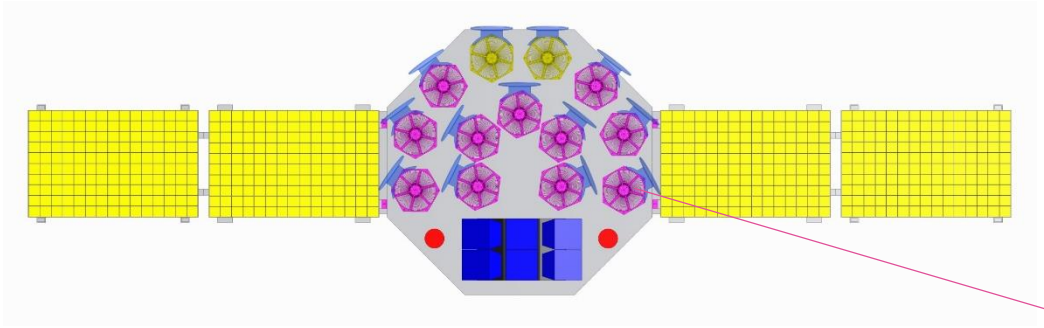
- Short focal-length for multiple modules
- Deployable panel for collimated modules
- Polarimeter with imaging capability
- Wide field monitor

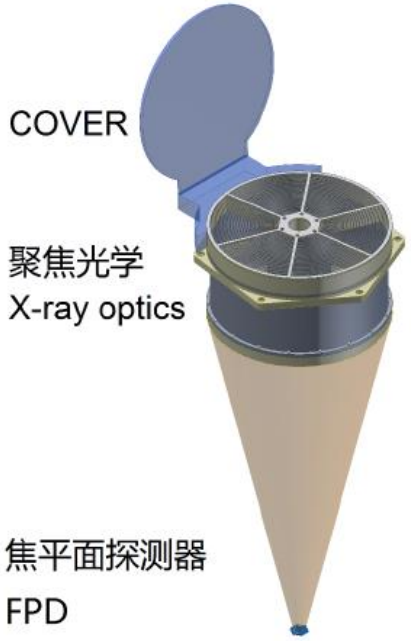




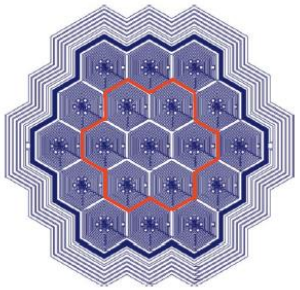
eXTP Scientific Payload

SFA – Spectroscopy Focusing Array



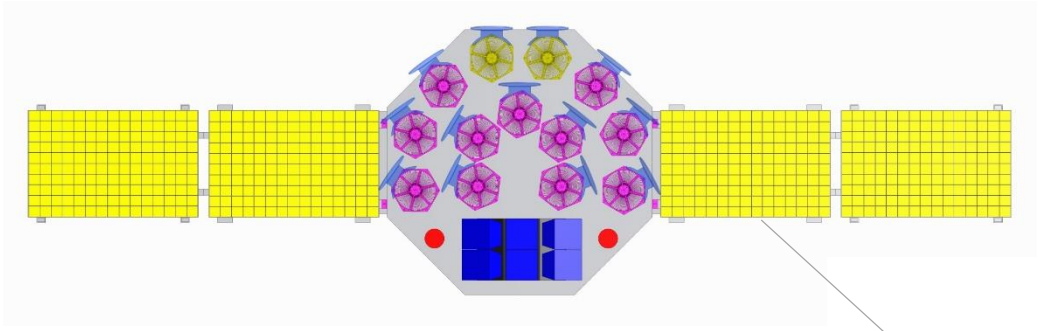


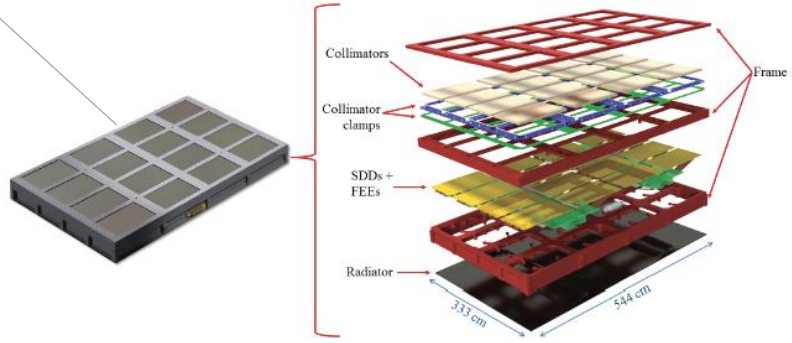
- Large collecting area achieved by multiple optics with short focal length. Baseline: 11 optics with 4.5m focal length
- Non-imaging, PSF requirement 1 arcmin HPD, 12’ FoV
- Non-imaging SDD detector: multipixel to enable background subtraction. Single photon, <100μs
- Energy band: 0.5-10 keV
- Energy resolution: <180 eV FWHM @6 keV
- Total effective area: 0.9 m^2 @1 keV, 0.6 m^2 @6 keV



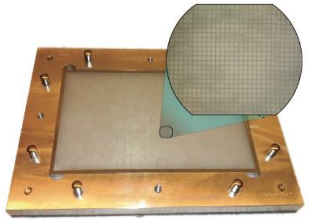
eXTP Scientific Payload

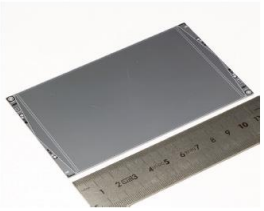
LAD – Large Area Detector





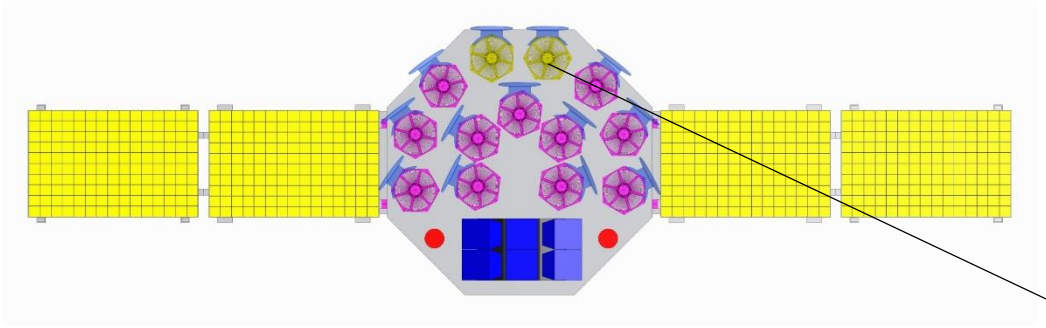
- Based on the LOFT/LAD design
- 40 Modules on 2 deployable panels
- Collimated, large-area SDD detector. Singıe photon, <10µs
- Energy band: 2-30 keV
- Energy resolution: <240 eV FWHM @6 keV
- Total effective area: 3.4 m^2 @8 keV

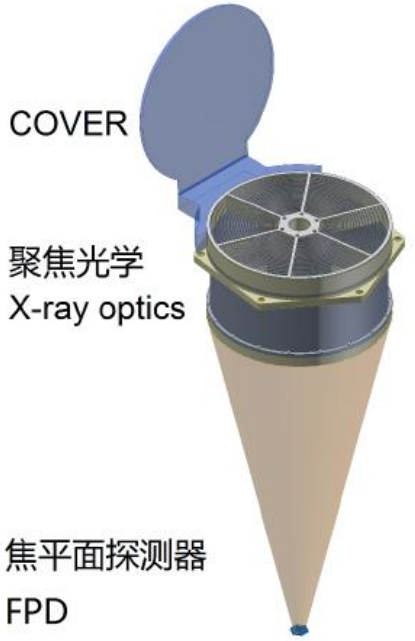




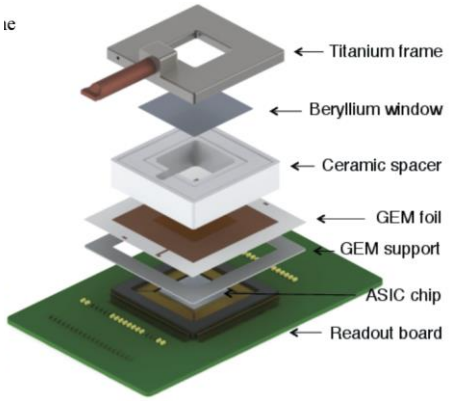
eXTP Scientific Payload

PFA – Polarimetry Focusing Array



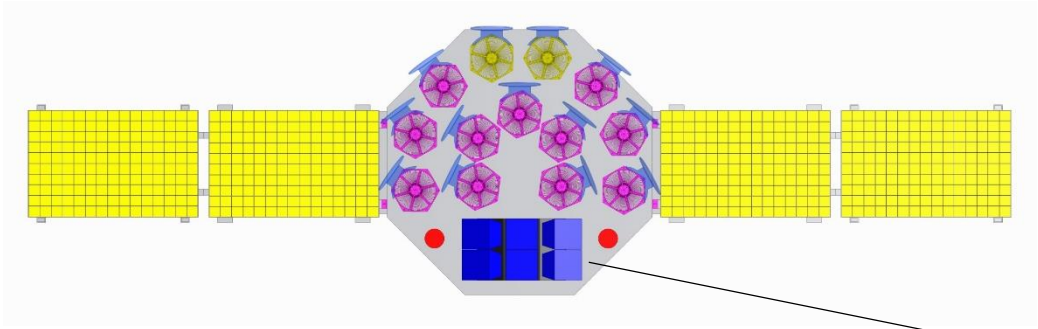


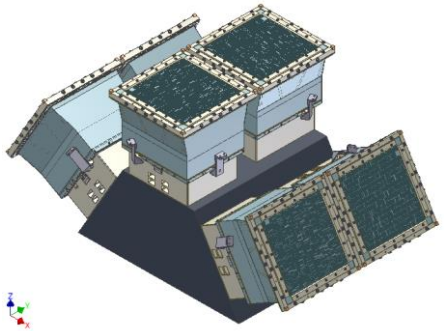
- Focal plane imaging polarimeter. Baseline: 2 optics with 4.5m focal length
- Imaging, PSF requirement 15 arcsec HPD
- Gas Pixel Detector: photo-electron tracking. Single photon, <100μs
- Energy band: 2-10 keV
- Energy resolution: 20% FWHM @6 keV
- Total effective area: 240 cm^2 @6 keV



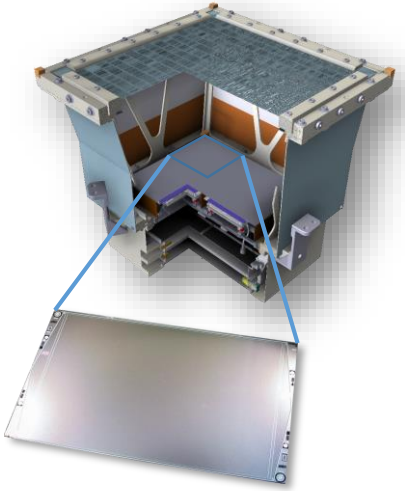
eXTP Scientific Payload

WFM – Wide Field Monitor



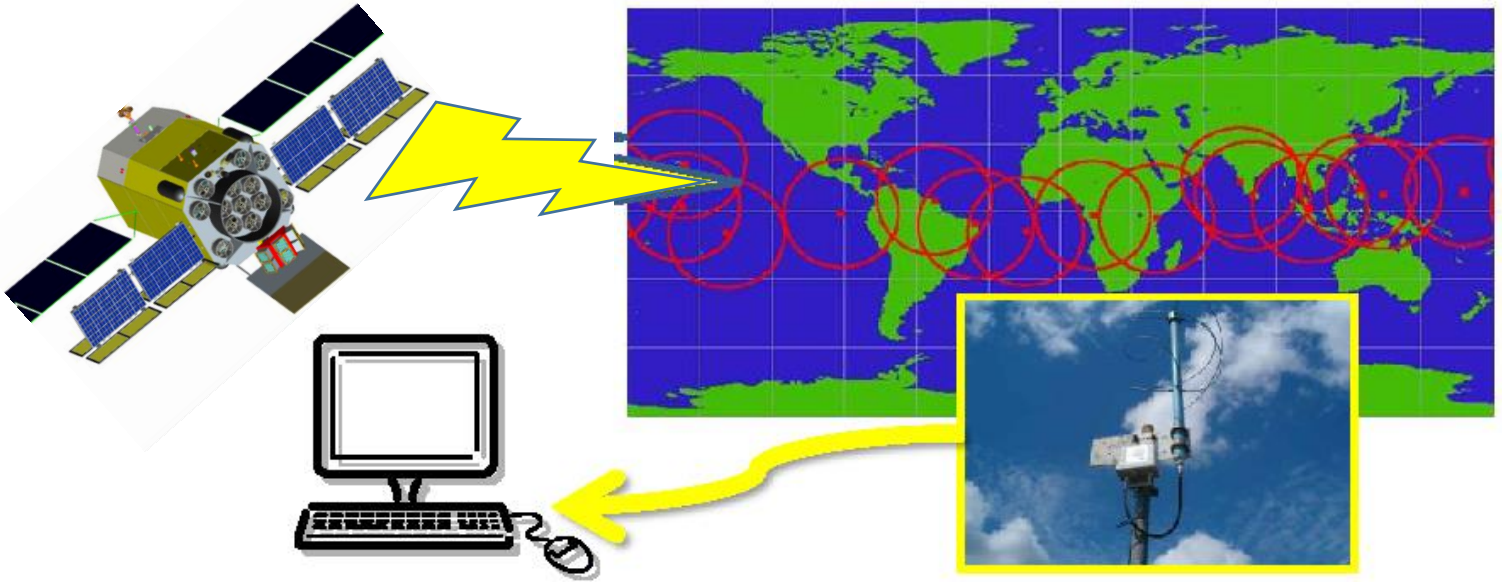


- Same design as LOFT/WFM, 3 units (6 cameras)
- Imaging, 4 arcmin angular resolution, 1 arcmin PSLA
- Field of View: 4 steradian (at 20% response)
- Same detectors as LAD (SDD). Single photon, <10μs
- Energy band: 2-50 keV
- Energy resolution: 300 eV FWHM @6 keV
- Effective area: 80 cm^2 @6 keV (1 unit,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



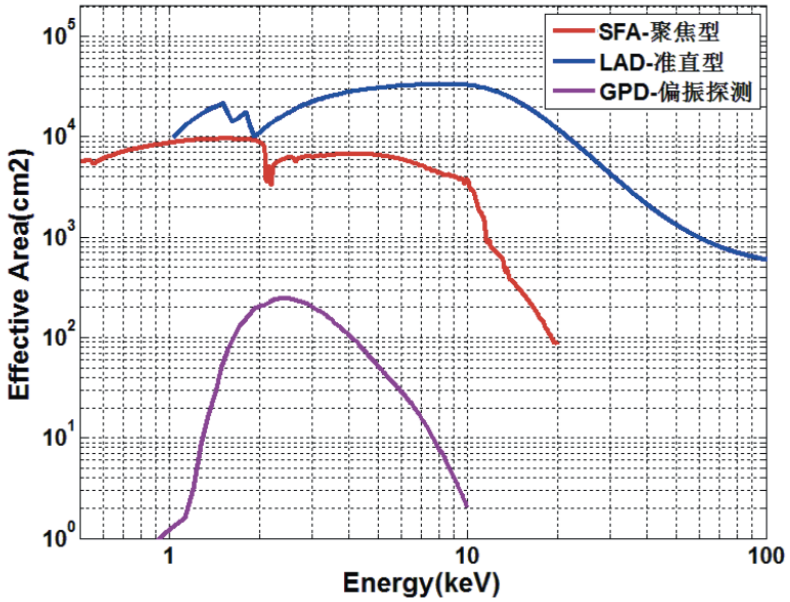
eXTP Burst Alert System

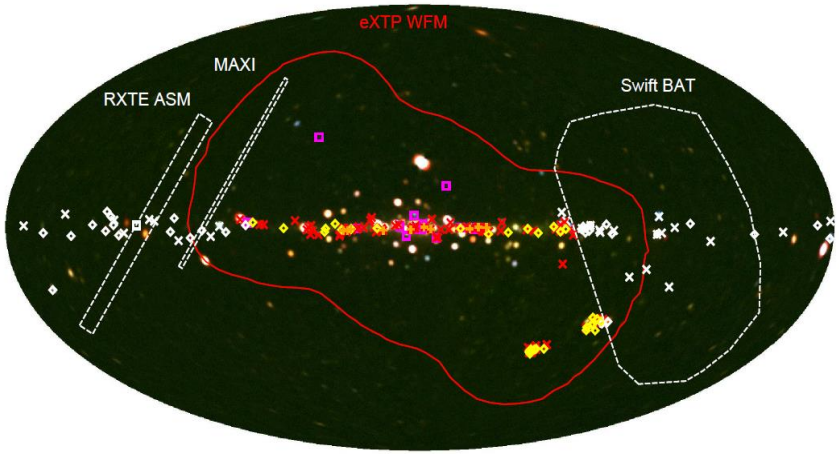
- The large field of view of the WFM provides unique opportunities for detecting Gamma Ray Bursts (~100 GRBs per year)
- **Onboard Burst Trigger** and Localization
- **Onboard VHF transmitter** to transmit short message with time and sky position
- Network of small ground stations to receive message (SVOM)
- Delivery of trigger time and burst position to end users within 30 s for fast follow up of the fading GRB afterglow



eXTP Scientific Payload

Performance

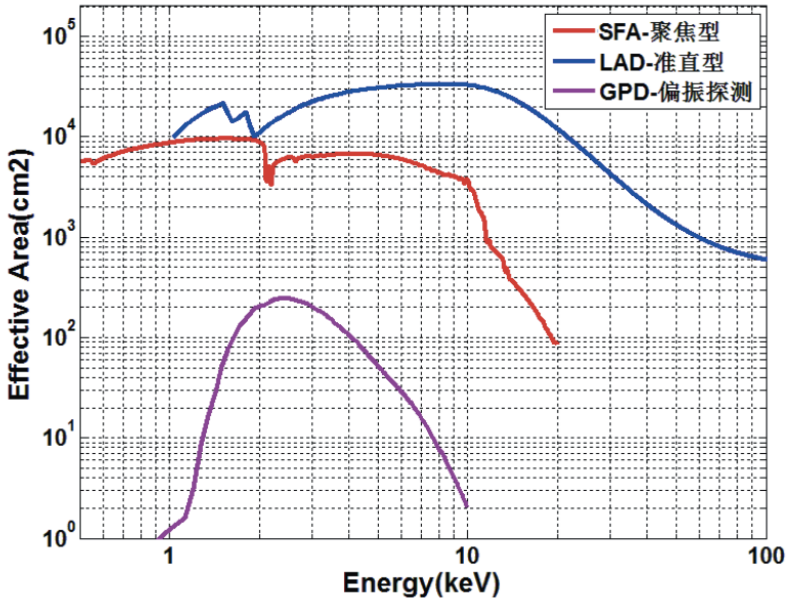


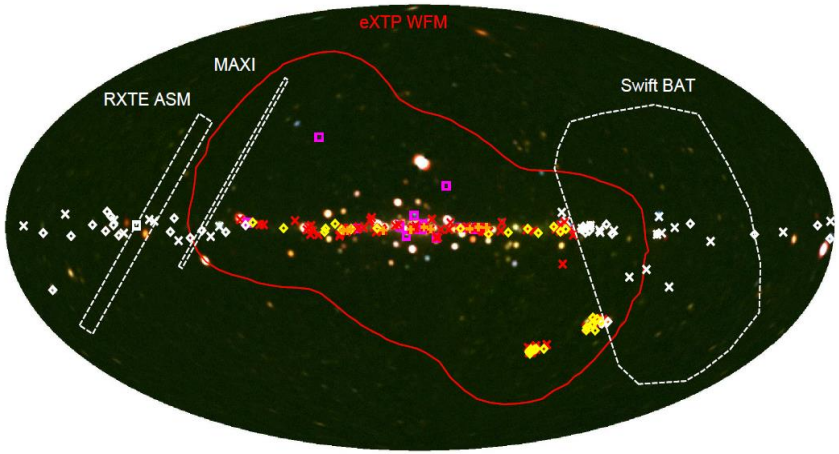


- ❖ LAD: 6x RXTE/PCA, 35x XMM-Newton (*but collimated*!) + hard-X response
- ❖ SFA: 10x XMM-Newton and 0.5x Athena/WFI (*but multiple optics*!).
  Limiting sensitivity ~10^{-14}-10^{-15} erg cm^{-2} s^{-1}
- ❖ PFA: 2x IXPE, same as XIPE. Sensitivity: 1% MDP in 65ks for a 100 mCrab source
- ❖ WFM: largest FoV ever, first time with 300 eV energy resolution.
  Sensitivity: 3 mCrab in 50ks

eXTP Scientific Payload

Performance





- LAD:
- SFA:
- PFA: source
- WFM: largest FoV ever, first time with 300 eV energy resolution.
  Sensitivity: 3 mCrab in 50ks

Point open for discussion: increase the number of PFA units (e.g., from 2 to 4), at the expenses of the SFA units?

eXTP Mission Profile

Parameter	Value
Orbit	550 km, 14° inclination (goal <2.5°)
Launcher	Long-March CZ-3C, 4200X fairing (goal CZ-7)
Mass	3700 kg
Power	3.6 kW
Telemetry	3 Tb/day
Ground Stations	China, Malindi
Pointing	3-axis stabilized, < 0.01°
Sky visibility	50% (goal 75%)
Mission Duration	5 years (goal 10 years)
Launch date	2024

eXTP Preliminary Schedule

- 2011-2016: background study (Phase 0/A1)
- 2017: international coordination and preliminary design (Phase A2)
- 2018: Detailed design (Phase B)
- 2019-2021: Space qualification model (Phase C)
- 2022-2023: flight model (Phase D)
- **2024: launch**

- 2025-2035: science observation

Potential participating institutions

esa

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

UCL MSSL

MPE

UNIVERSITÉ DE GENÈVE

CSIC

IEEC INSTITUT D'ESTUDIS ESPACIALS DE CATALUNYA

cea

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

ISDC

DTU

INFN

University of Leicester

CBK PAN

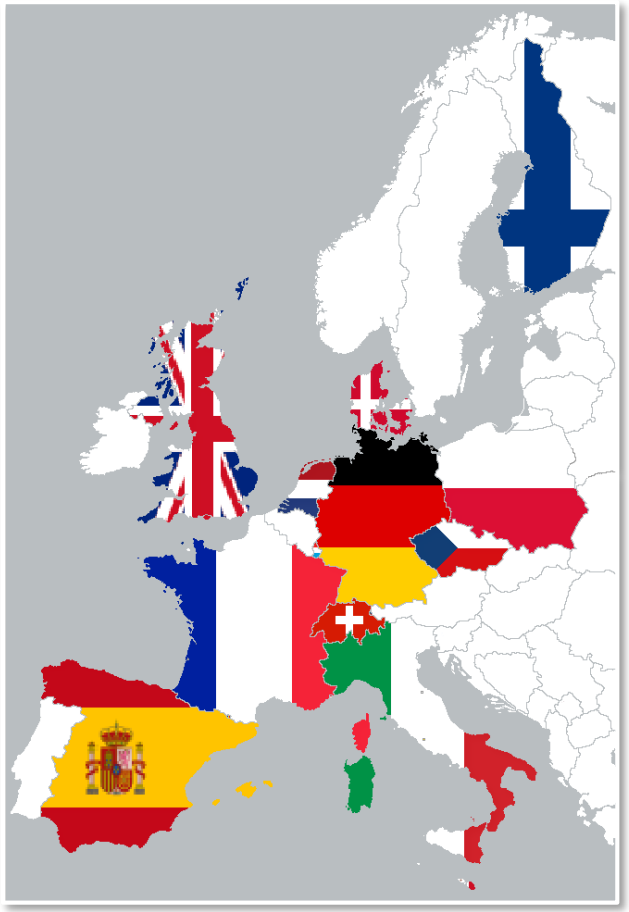
Turun yliopisto University of Turku

UNIVERSITY OF AMSTERDAM

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

SRON

इसरो isro



eXTP Data Policy

eXTP is proposed an observatory open to the worldwide science community.

The specific data policy will be discussed by the participating agencies at later stages in the development of the mission. However, it is expected that the eXTP observing plan will be designed based on Core Program observations as well as on a Guest Investigator Program, through time allocation committees.

eXTP Science Working Groups

- In support to the mission evaluation in China, four international working groups were preliminarily formed on the main science topics, producing 4 White Papers (advanced drafts):
  - Accretion in Strong Field Gravity
  - Dense Matter
  - Strong Magnetism
  - Observatory Science
- In the framework of the upcoming joint China-Europe study of eXTP, we encourage further support and extended participation to the Science Working Groups, leading (also) to an update of the White Papers. Subscriptions to contribute to the Science Workign Groups are open. Please register at: http://www.isdc.unige.ch/extp/swg-registration.html
- The 4 eXTP WPs are expected to be published on a special issue of the Science China journal in about 6 months. Further studies and updates will be published at the end of the study, together with the joint study report.

Conclusions

eXTP is conceived as the most powerful and general observatory for compact Galactic and extragalactic objects ever.

eXTP will change the game. It will offer for the first time the most complete diagnostics of compact sources: excellent spectral, timing and polarimetry sensitivity on a single payload.

eXTP has to be a cooperative effort between (at least) **China and Europe**. China is leading the project and Europe has now a unique opportunity to join and provide its scientific community with the X-ray observatory for the next decade.

The support and contribution of the wide scientific community is crucial to achieve this goal.