Astronomia X Made in China

在中國製造的X-射線天文學

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INAF/IASF, UZG

The enhanced X-ray Timing Polarimetry Mission

增強的X射線計時和旋光測量任務

Zhang, S. N., Feroci, M., Santangelo A., et al., 2016, Proc. of the 2016 SPIE Conference, Vol. 9905, **arXiv:1607.08823**

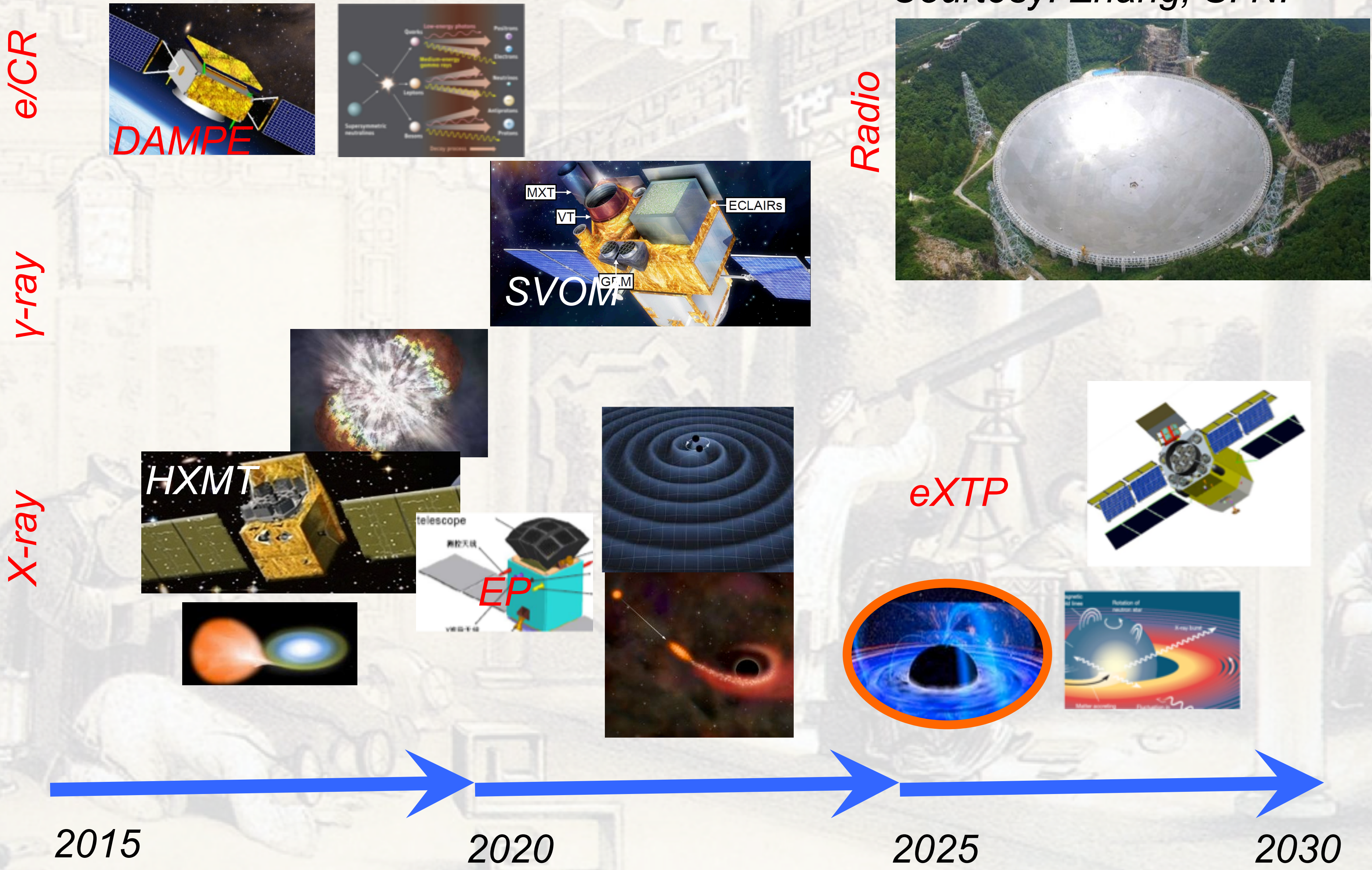

High-throughput X-ray Astronomy
in the eXTP era
eXTP开启高产出X射线天文新纪元
6-8 February 2017 - Rome, Italy
Scientific Organizing Committe:
Marco Feroci (INAF-IAPS Rome, Italy; co-chair)
Shuang-Nan Zhang (IHEP, China; co-chair)
Andrea Santangelo (IAAT, Germany; co-chair)
Cosimo Bambi (Fudan University, China)
Sudip Bhattacharyya (TIFR, India)
Enrico Bozzo (University of Geneva, Switzerland)
Soren Brandt (DTU, Denmark)
Deepto Chakrabarty (MIT, United States)
Wei Cui (Purdue University, United States)
Zigao Dai (Nanjing University, China)
Hua Feng (Tsinghua University, China)
Margarita Hernanz (IEEC-CSIC, Spain)
Michiel van der Klis (UVA, The Netherlands)
Dong Lai (Cornell University, United States)
Piotr Orleanski (Space research Center, Poland)
Paul Nandra (MPE, Germany)
Giovanni Pareschi (INAF-OA Brera, Italy)
Martin Pohl (University of Geneva, Switzerland)
Rashid Sunyaev (MPA, Germany)
Stephane Schanne (CEA, France)
Zhanshan Wang (Tongji University, China)
Silvia Zane (MSSL-UCL, United Kingdom)
Shu Zhang (IHEP, China)
Local Organizing Committe:
Enrico Bozzo (University of Geneva, Switzerland;chair)
Gabriella Ardizzoia (CIFS - Torino, Italy)
Sergio Di Cosimo (INAF-IAPS Rome, Italy)
Yuri Evangelista (INAF-IAPS Rome, Italy)
Marco Feroci (INAF-IAPS Rome, Italy)
Giuliano Sabatino (Rome, Italy)
Chris Tenzer (IAAT, Germany)
Shu Zhang (IHEP, China)
Invited Speakers:
Andrei Beloborodov (Columbia Univ., USA)
Alessandra De Rosa (INAF-IAPS, Italy)
Hua Feng (Tsinghua Univ., China)
Jeremy Heyl (UBC, Canada)
Jean in 't Zand (SRON, Netherlands)
Gianluca Israel (INAF-OAR, Italy)
Arvind Parmar (ESA/ESTEC, The Netherlands)
Juri Poutanen (Univ. of Turku, Finland)
Luigi Stella (INAF-OAR, Italy)
Phil Uttley (UvA, The Netherlands)
Anna Watts (UvA, The Netherlands)
Renxin Xu (Peking Univ., China)
Wenfei Yu (SAO, China)
Shuang-Nan Zhang (IHEP, China)
http://www.isdc.unige.ch/extp/high-throughput-x-ray-astronomy-in-the-extp-era.html


esa
THE X-RAY UNIVERSE 2017

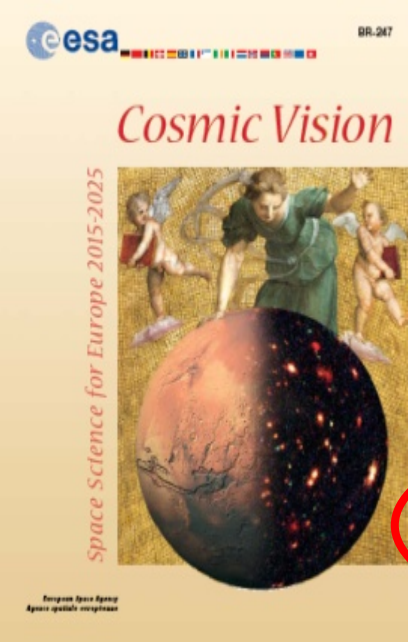

theseus
WORKSHOP 2017

China's HE Satellites

Courtesy: Zhang, S. N.



Preamble: LOFT, the Large Observatory For X-ray Timing



3. What are the fundamental physical laws of the Universe?

3.1 Explore the limits of contemporary physics

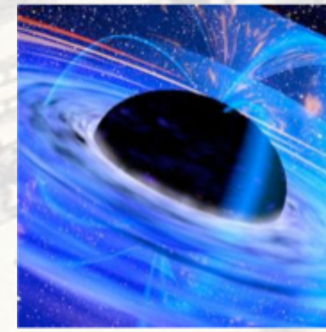
Use stable and weightless environment of space to search for tiny deviations from the standard model of fundamental interactions

3.2 The gravitational wave Universe

Make a key step toward detecting the gravitational radiation background generated at the Big Bang

3.3 Matter under extreme conditions

Probe gravity theory in the very strong field environment of black holes and other compact objects, and the state of matter at supra-nuclear energies in neutron stars



- LOFT was conceived as an experiment to address specific themes in the ESA Cosmic Vision Programme

Probe the state of matter at supra nuclear densities in Neutron Stars

Probe gravity theory in the very strong field environment of Black Holes

- Mission goals expanded to include those of an actual Observatory

Probe physics of hundreds of Galactic and bright extragalactic cosmic sources

LOFT Requirements

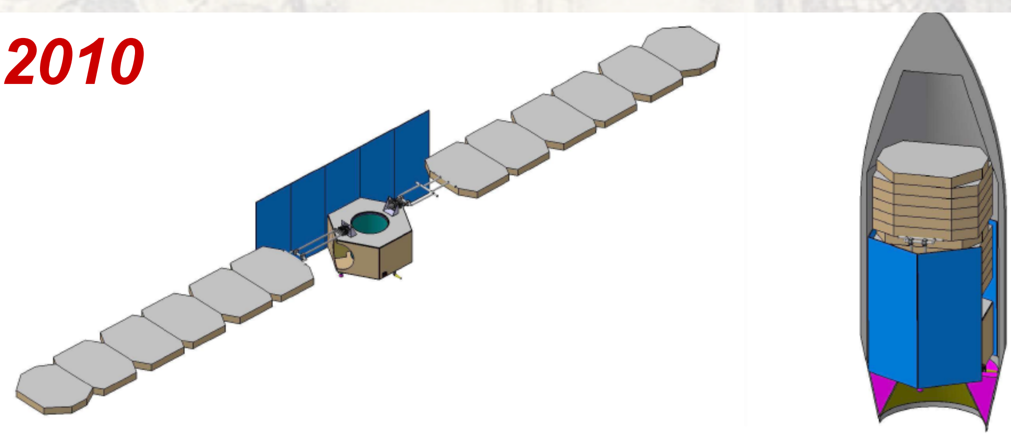
I. Exploit the Diagnostics of
X-ray Variability
on Dynamical Timescales (~0.1ms):
Large Collecting Area
(**~10m^2 @ 10 keV**)

III. Study a statistically representative source sample.
Sensitivity to fainter sources:
Large Collecting Area
(**~10m^2 @ 10 keV**)

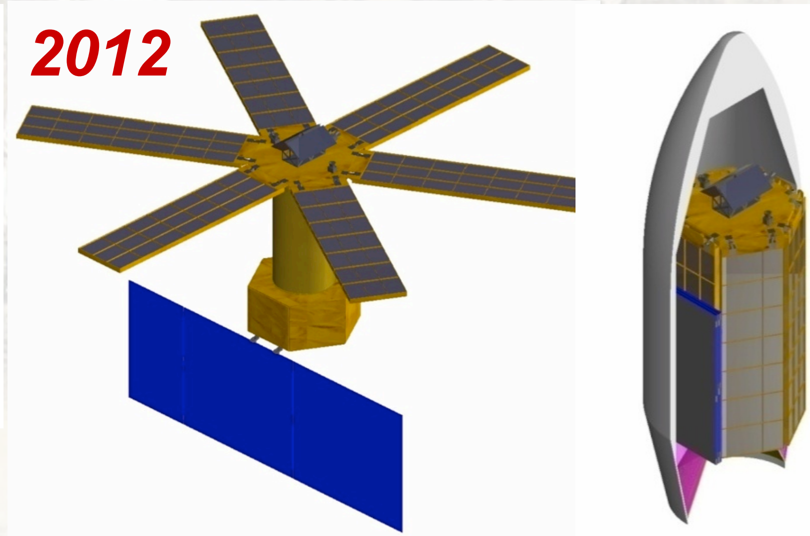
II. Exploit the Diagnostics of
Spectral Variability
on Dynamical Timescales (~0.1ms):
Good Energy Resolution
(**~200 eV @ 6 keV**)

Requirements met through **the employment of new detector technologies and new detector/satellite design**

2010

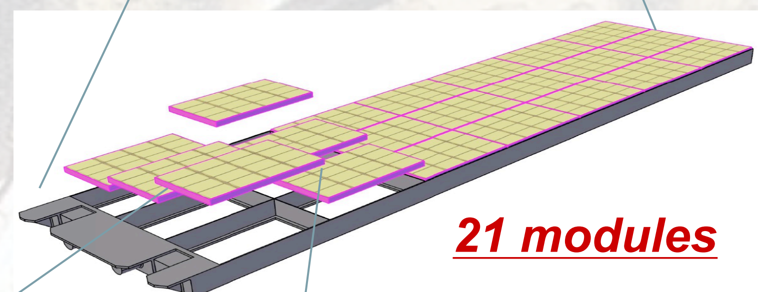


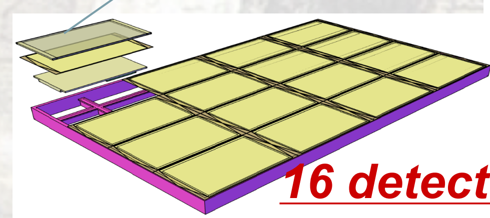
2012

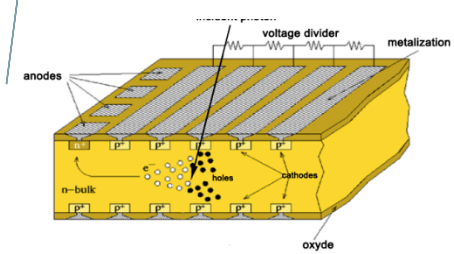


The Large Area Detector (LAD)

- Fully modular (126 detectors)
- Driving Technology: large-area Silicon Drift Detectors (SDD) – ALICE experiment @ CERN - and capillary plate collimators.

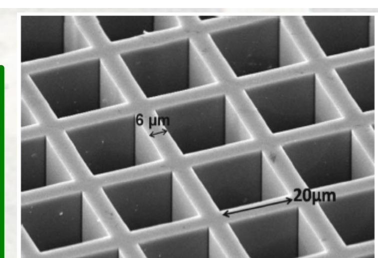






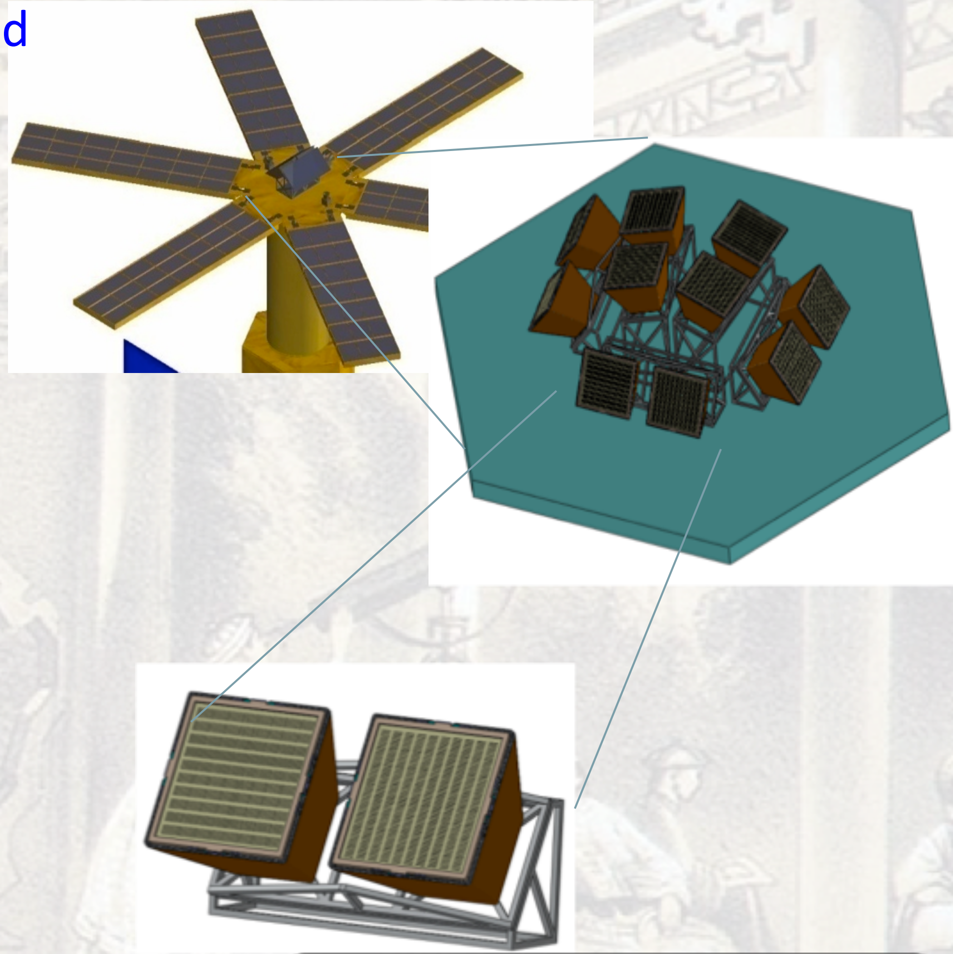
LAD – Large Area Detector	
Effective Area	4 m^2 @ 2 keV 8 m^2 @ 5 keV 10 m^2 @ 8 keV 1 m^2 @ 30 keV
Energy range	2-50 keV primary 2-80 keV goal
Energy resolution FWHM	260 eV @ 6 keV 200 eV @ 6 keV (45% of area)
Collimated FoV	1 degree FWHM
Time Resolution	10 µs
Absolute time accuracy	1 µs
Dead Time	<1% at 1 Crab
Background	<10 mCrab (<1% syst)
Max Flux	500 mCrab full event info 15 Crab binned mode

Low weight/power/volume per unit effective area
1m^2 ~ 100 kg

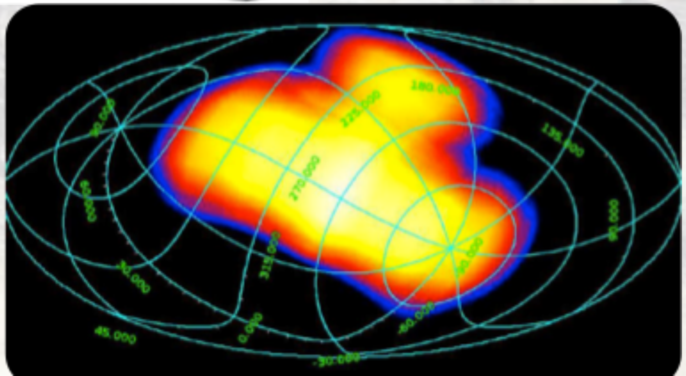


The Wide Field Monitor (WFM)

- 5 Independent Units, each one composed of 2 cameras.
- SDDs plus coded mask aperture
- WFM FoV coverage ~33% of the sky at any time in the 2-50 keV range



WFM- Wide Field Monitor	
Energy range	2-50 keV primary 50-80 keV extended
Active Detector Area	1820 cm^2
Energy resolution	300 eV FWHM @ 6 keV
FOV (Zero Response)	4.1 steradians
Angular Resolution	5’ x 5’
Point Source Location Accuracy (10-σ)	1’ x 1’
Sensitivity (5-σ, on-axis) Galactic Center, 3 s Galactic Center, 1 day	 270 mCrab 2.1 mCrab
Standard Mode	5-min, energy resolved images
Trigger Mode	Event-by-Event (10μs res) Realtime downlink of transient coordinates



LOFT History

- Candidate M3 mission in February 2011 (+64). Down-selection in February 2014: PLATO selected with LOFT ranked second by the **ESA Astronomy Working Group**

➢ The LOFT science was fully recognized as very strong and the mission suitable to address it.

➢ The LOFT technology was evaluated as mature and the mission feasible within the boundaries of an ESA M-class mission.

➢ The non-overlap between the LOFT and Athena science cases was also clearly acknowledged.

- LOFT 2.0 re-proposed for M4. Budget decreased to 450 M€. LOFT 2.0 slightly descoped
  - LAD 10 to 8m^2 effective area

- LOFT M4 proposal submitted and passed the first programmatic/technical evaluation screening but not selected – another proposed X-ray mission (*XIPE)*

- LoI sent to ESA but LOFT not proposed for M5

X-ray Timing Explorer (XTP)

- Key Science: Matter under extreme conditions, exactly like LOFT (and Strobe-X)!

- Precise Light curve: Neutron Star equation of state,
  BH basic parameters, formation and growth …

- X-ray Polarization: Radiation mechanism…

- Diffuse X-ray emission, hot gas distribution in Galaxy

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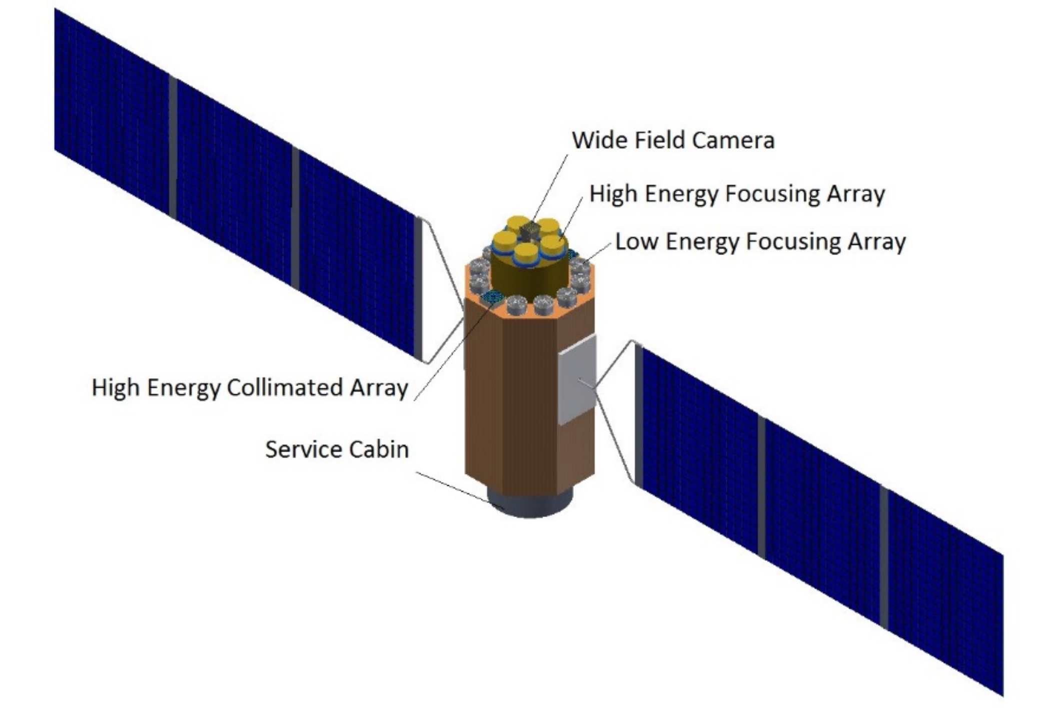
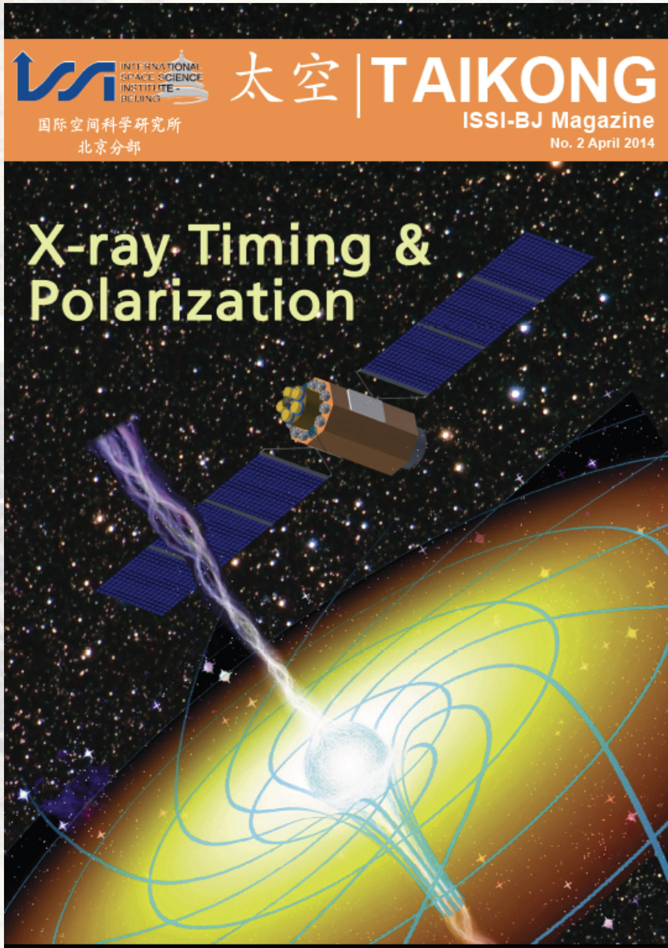
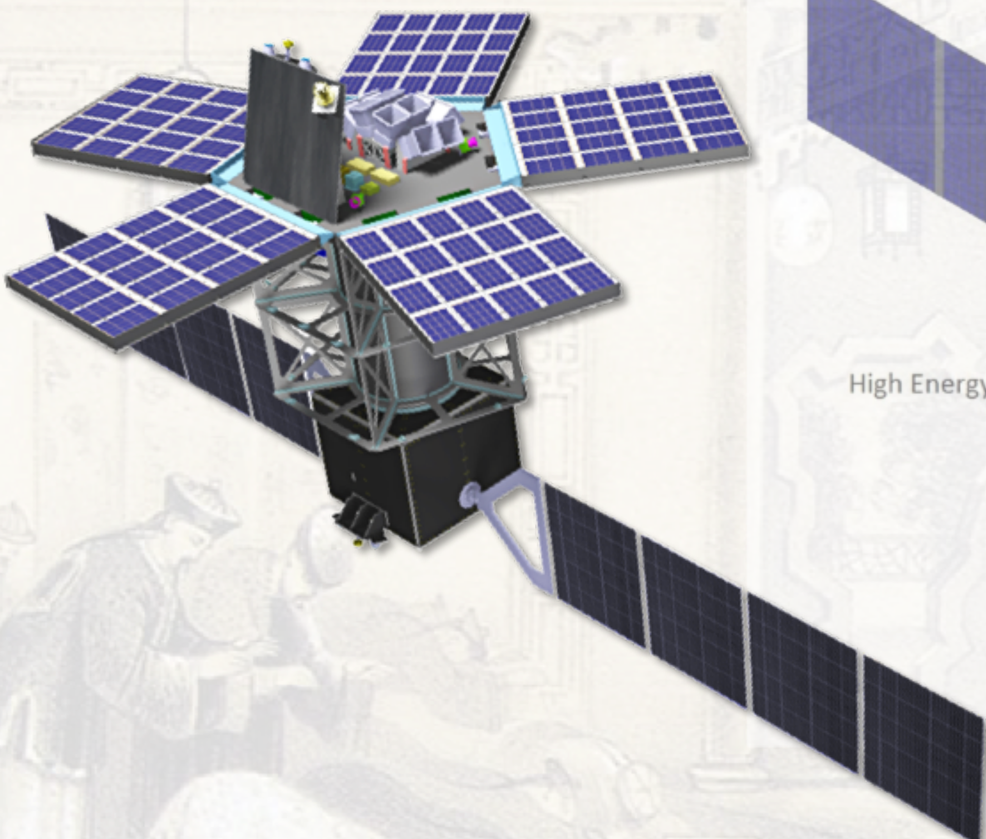
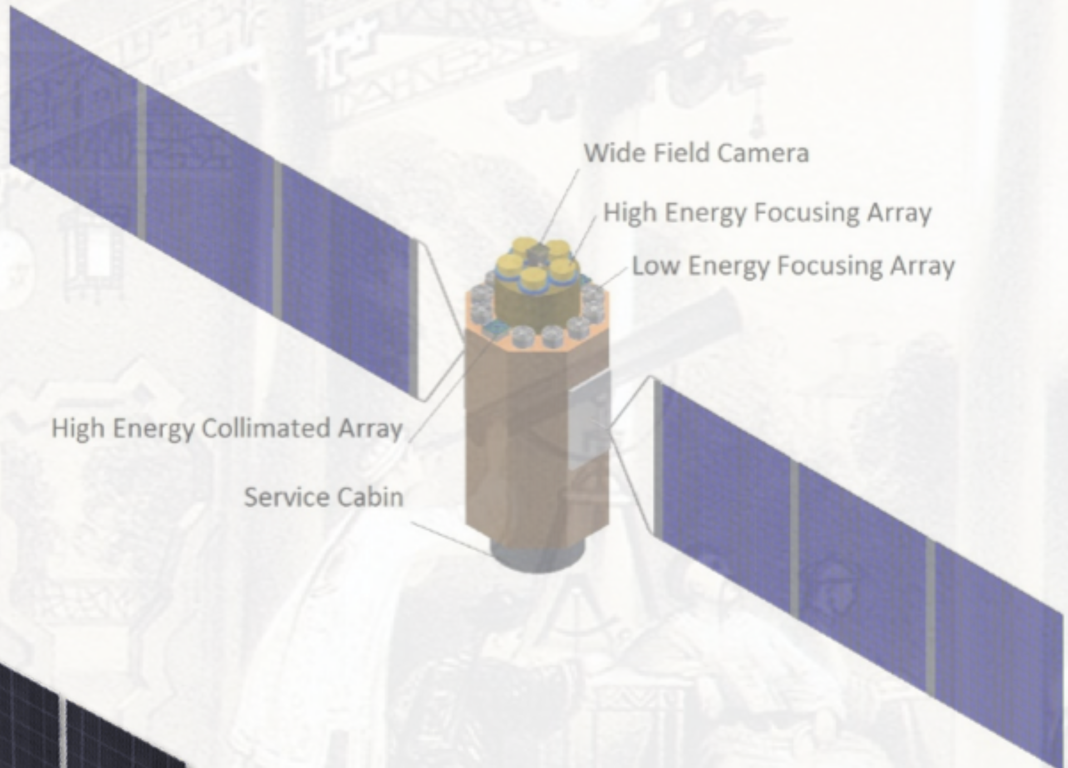




LOFT + XTP → eXTP [not eLOFT]





The eXTP International Consortium

Principal Investigator:
Shuang-Nan Zhang
IHEP/CAS

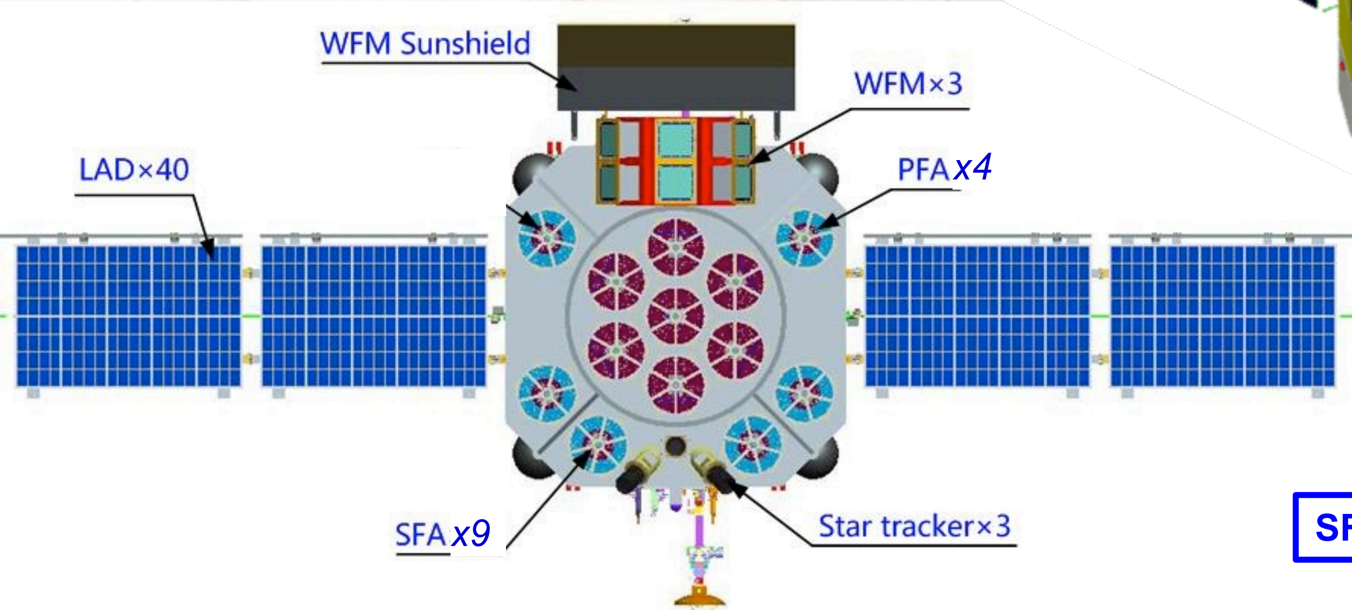
- CAS — 中国科学院 CHINESE ACADEMY OF SCIENCES
- CNSA
- IHEP Beijing — Institute of High Energy Physics, Chinese Academy of Sciences
- Tsinghua University — 清华大学 Tsinghua University
- Tongji University — 同济大学 TONGJI UNIVERSITY
- CAST — 中国空间技术研究院 China Academy of Space Technology 中国航天

- Italy: INAF, INFN
- Germany: Eberhard Karls Universität Tübingen, MPE, FAU Friedrich-Alexander Universität Erlangen-Nürnberg
- France: cea
- Spain: CSIC, IEEC Institut d'Estudis Espacials de Catalunya
- Switzerland: Université de Genève, ISDC
- Denmark: DTU
- Poland: CBK, CAMK PAN
- Czech Republic: asu Astronomical Institute of the Czech Academy of Sciences
- United Kingdom: UCL MSSL, University of Leicester
- The Netherlands: University of Amsterdam, SRON

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



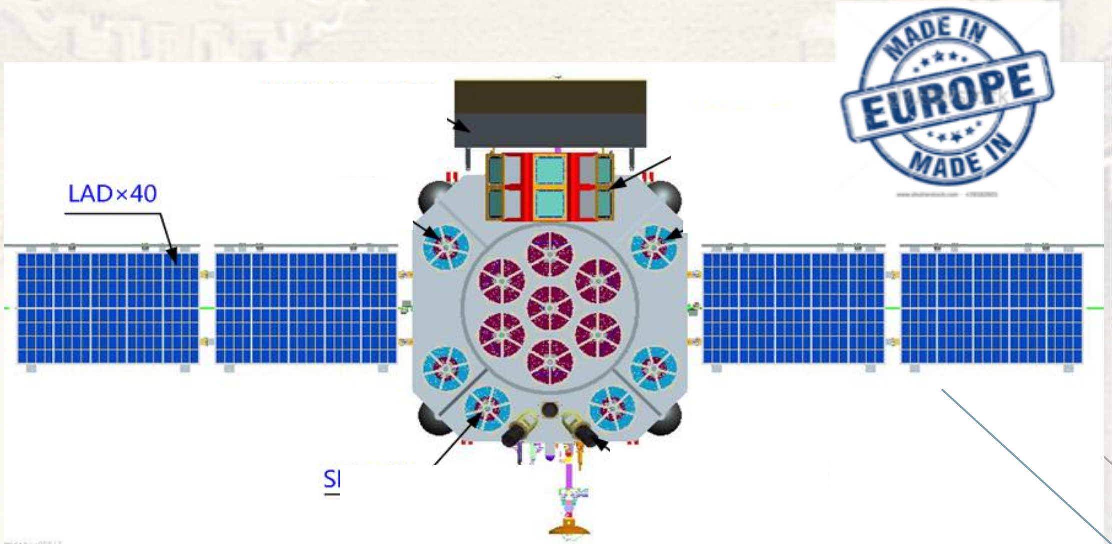
LAD- Large Area Detector

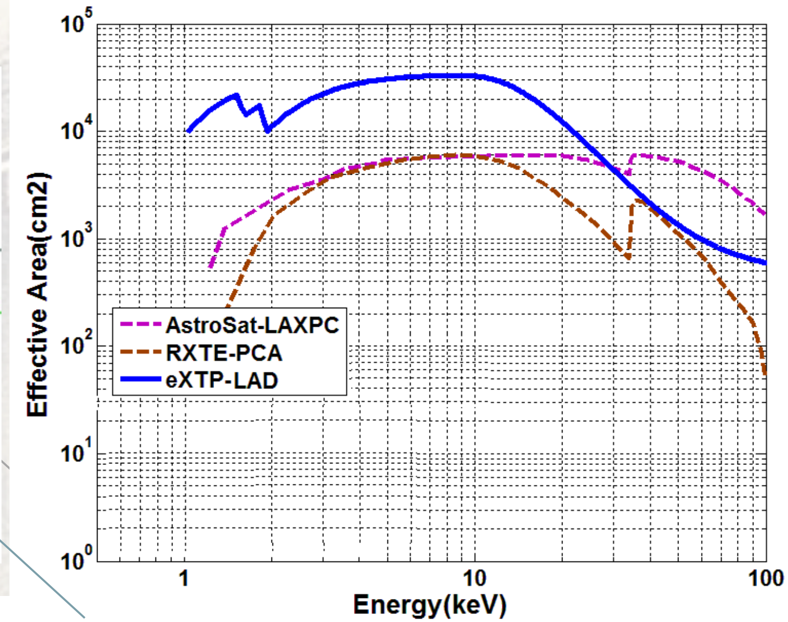
SFA- Spectroscopy Focusing Array

PFA- Polarimetry Focusing Array

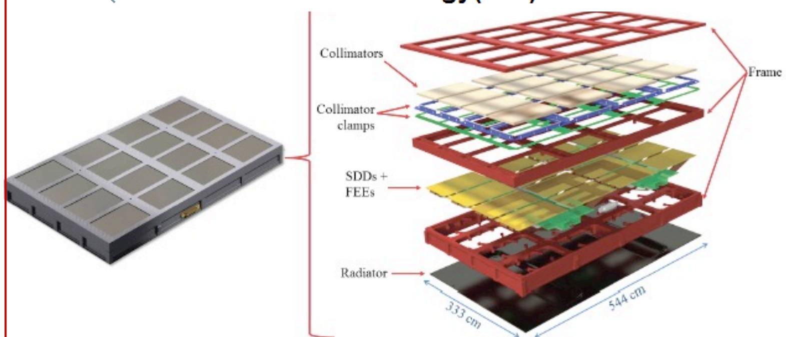
WFM- Wide Field Monitor

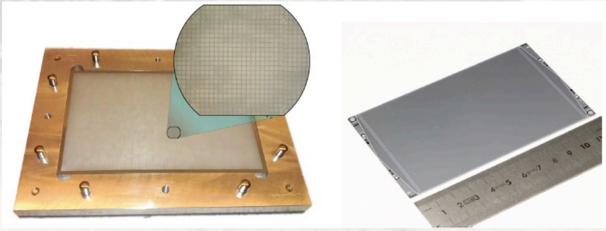
LAD – Large Area Detector



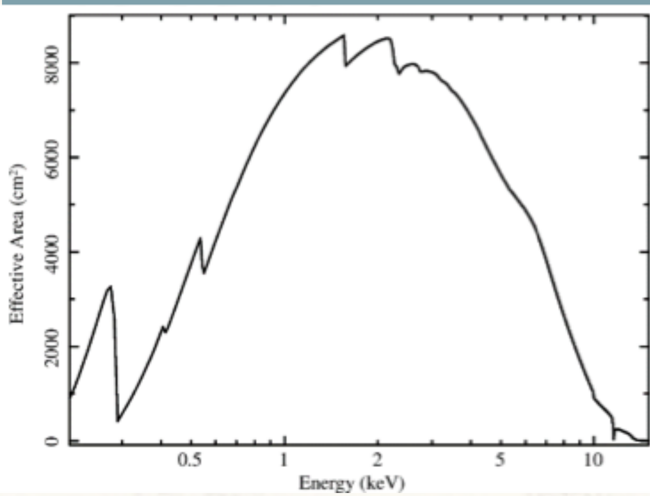


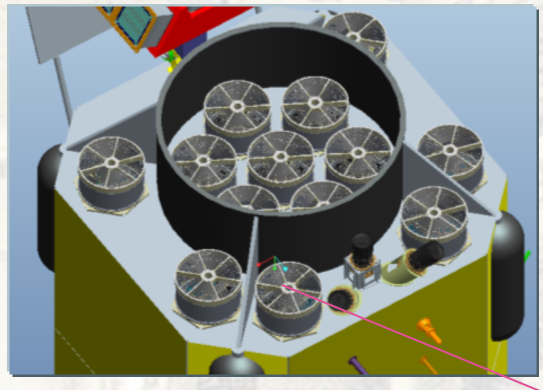
- Based on the LOFT/LAD design
- 40 Modules on 2+2 deployable panels
- Collimated, large-area SDD detector.
- Single photon, <10μs
- Total effective area: 3.4 m^2 @8 keV
- Energy band: 2-30 keV
- Energy resolution: <240 eV FWHM @6 keV

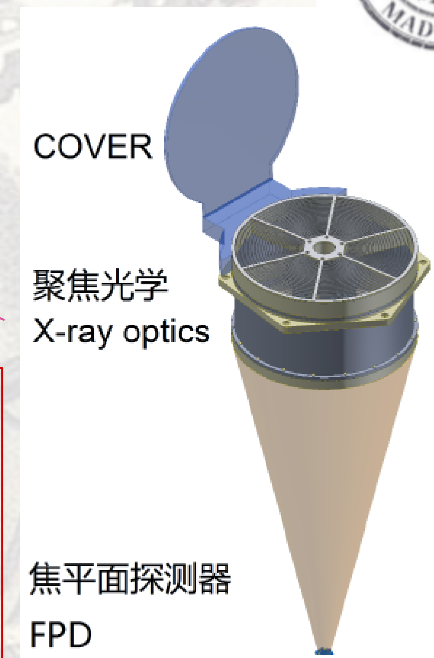




SFA – Spectroscopy Focusing Array





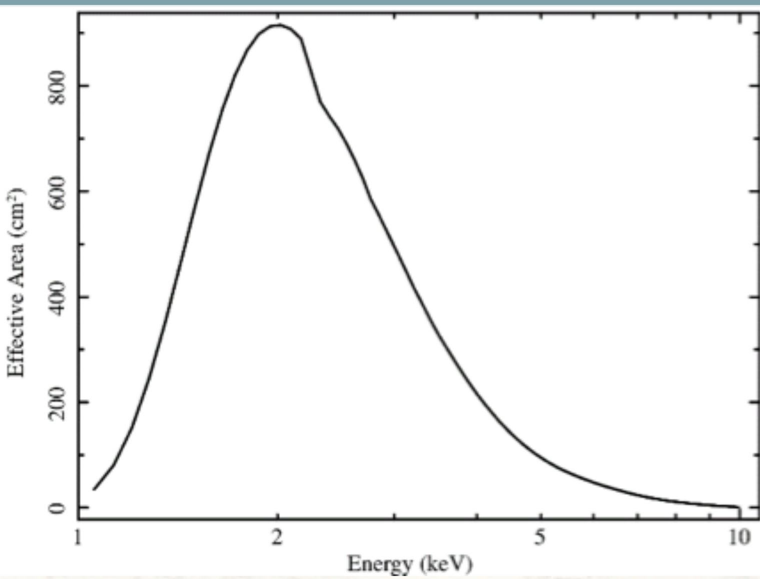


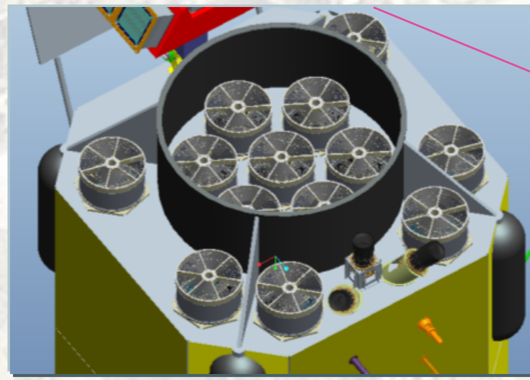
- Large collecting area achieved by multiple optics with short focal length. Baseline: 9 optics with 5.25m FL
- Non-imaging, PSF requirement 1 arcmin HPD, 12’ FoV
- Multi-pixel SDD detector
- Single photon, <100µs
- Energy band: 0.5-10 keV
- Energy resolution: <180 eV FWHM @6 keV
- Total effective area: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

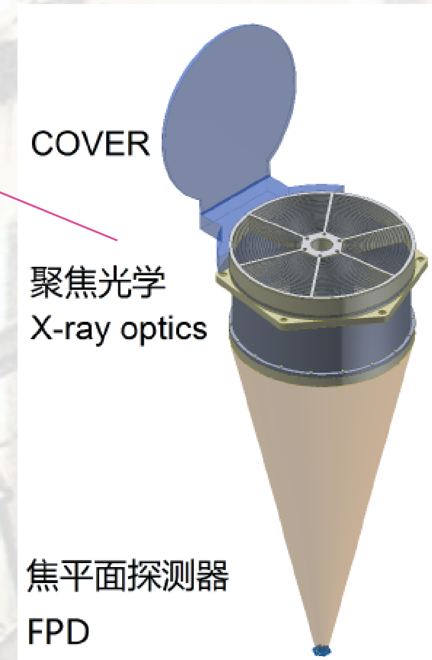
Complementary to the LAD

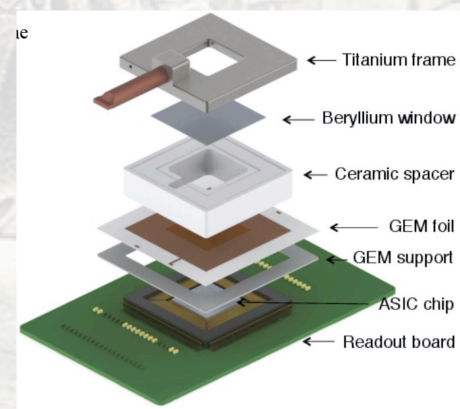
Lower effective area wrt the LAD

PFA – Polarimetry Focusing Array



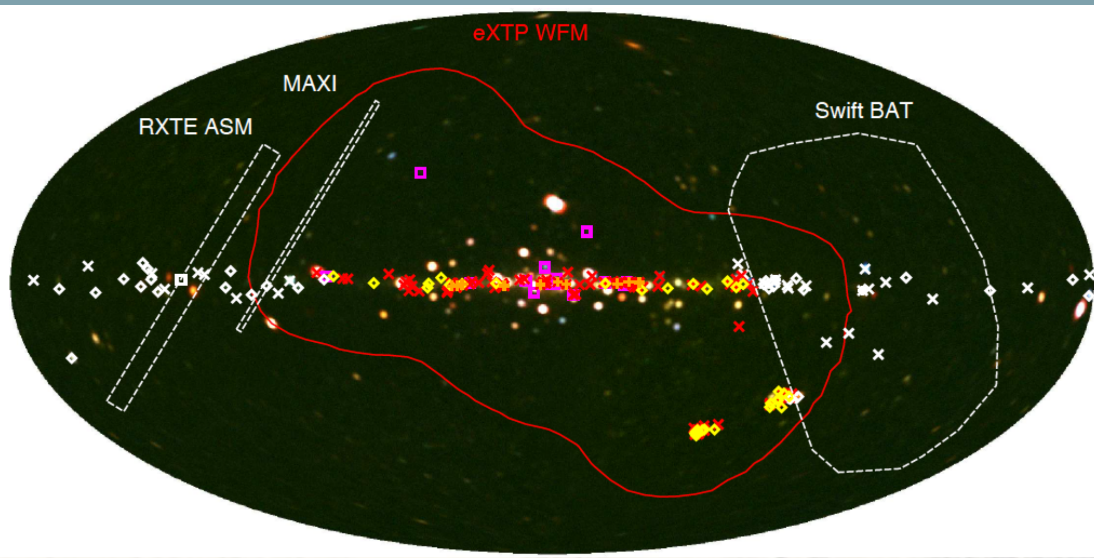


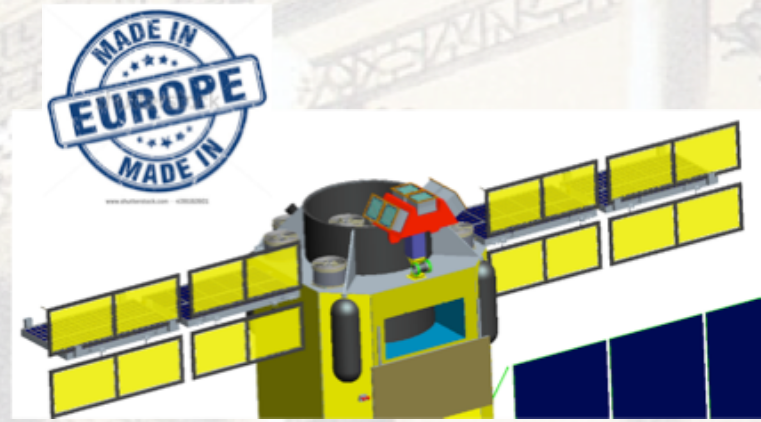


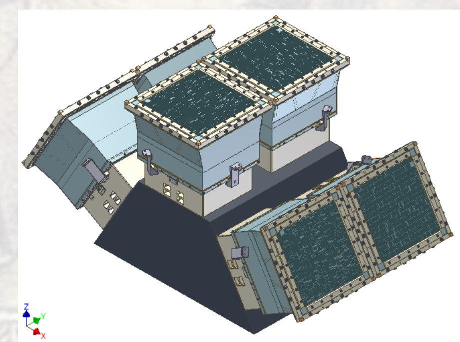


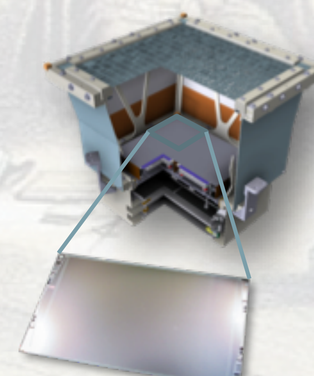
- Focal plane imaging polarimeter: 4 optics with 5.25m FL
- Imaging, PSF 20 arcsec HPD
- Gas Pixel Detector
- Single photon, <100μs
- Energy band: 2-10 keV
- Energy resolution: 20% FWHM @6 keV
- Total effective area: 900 cm^2 @2 keV (includes QE)

WFM – Wide Field Monitor





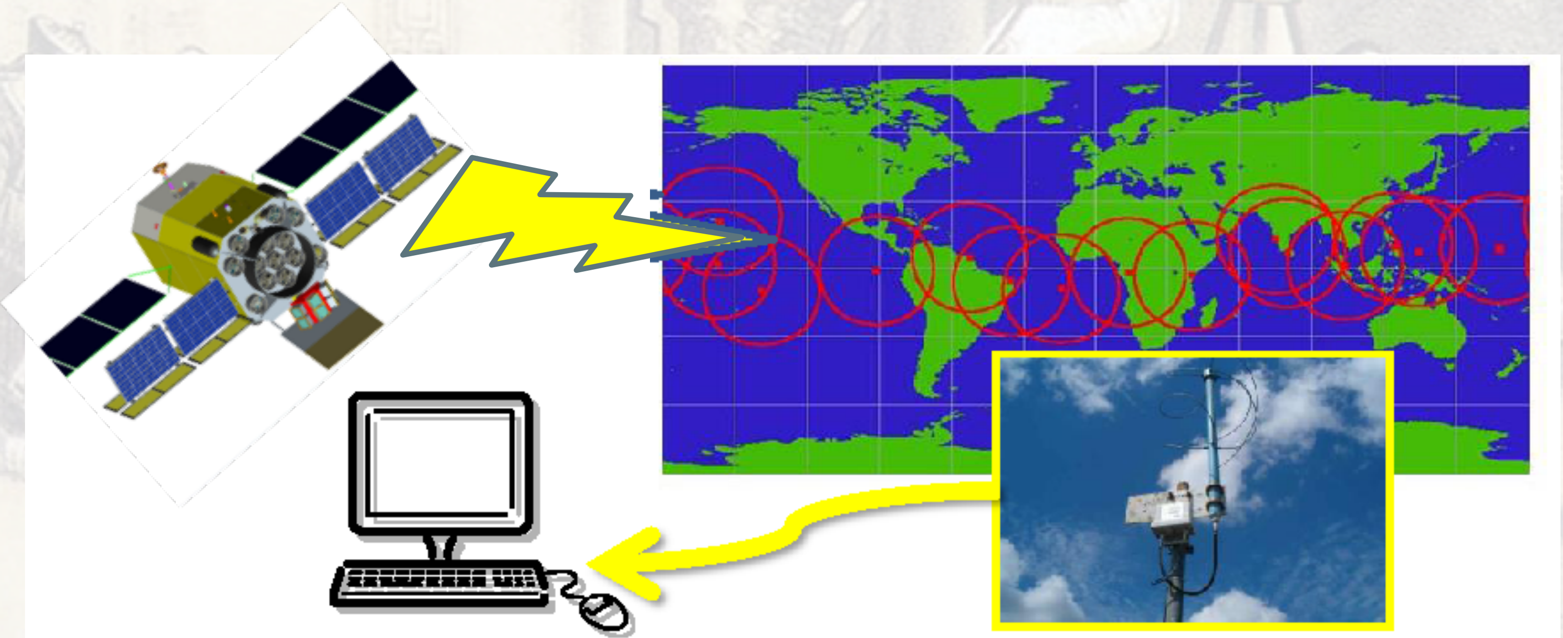


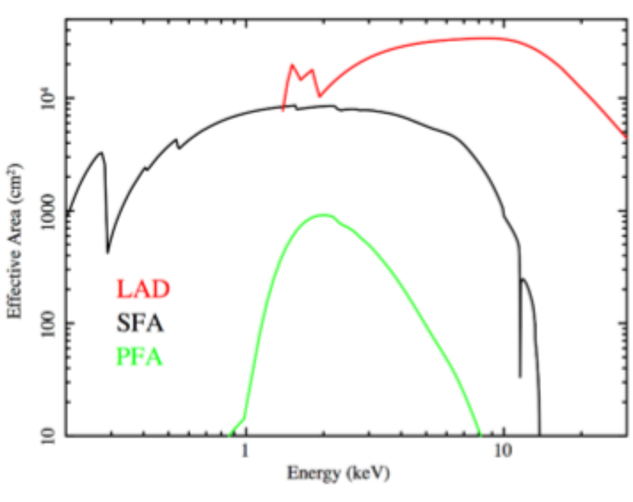


- Same design as LOFT/WFM, 3 units (6 cameras)
- Same detectors as LAD (SDD). Single photon, <10μs
- Field of View: 4 steradian
- Imaging, <5 arcmin angular resolution, 1 arcmin PSLA
- Energy band: 2-50 keV
- Energy resolution: 300 eV FWHM @6 keV
- Effective area: 80 cm^2 @6 keV (1 unit, on axis)

eXTP 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
- Delivery of trigger time and burst position to end users within 30 s for fast follow up of the fading GRB afterglow





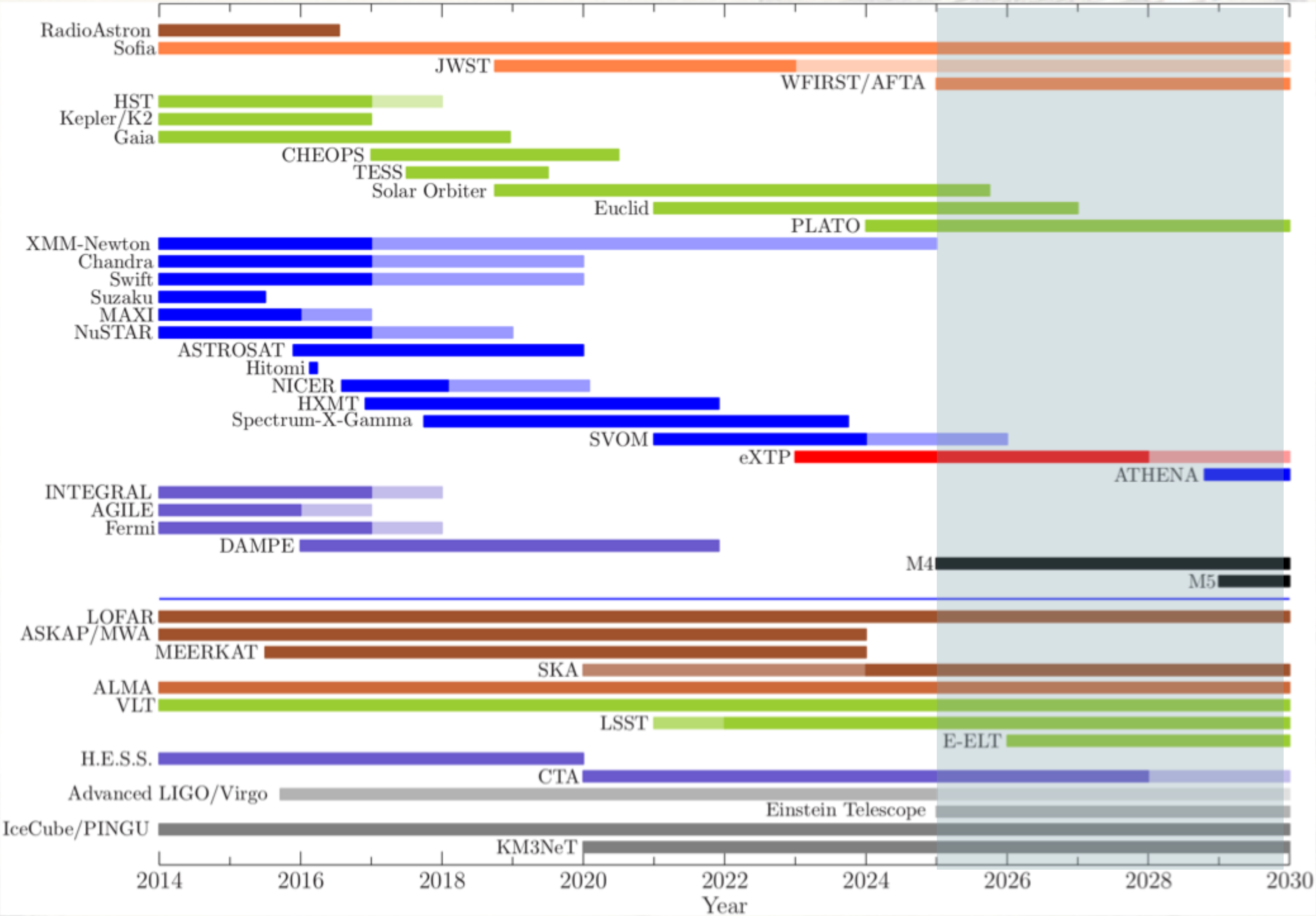
P/L	Parameter	Specification
SFA	Energy range	0.5-10 keV **Soft Response**
	Effective area	>7000 cm^2 @1 keV, >5000 cm^2 @6 keV
	Energy resolution	<180 eV FWHM @6 keV
	FoV/HPSD	12 arcmin / 1 arcmin
	Detector	Pixelated SDD (19 pixels)
LAD	Energy range	2-30 keV (extended: 30-80 keV)
	Effective area	34000 cm^2 @8 keV **Large Area**
	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^2 @2 keV **Polarisation**
	Energy resolution	1.2 keV FWHM @6 keV
	FoV/HPD	12 arcmin / 20 arcsec
	Detector	GPD (4 units)
WFM	Energy range	2-50 keV
	Energy resolution	300 eV FWHM @6keV
	FoV	>4 sr **Monitoring**
	Angular resolution	<5 arcmin
	Localization	<1 arcmin
	Detector	Large area SDD

eXTP Programmatics

- Now in Phase A2 study, in collaboration with a consortium of European institutes. Formal European participation + ESA MoO (*Mission of Opportunity*) TBD.
- 2017-2018: international coordination and preliminary design (Phase A2)
  - 2019-2020: Detailed design (Phase B)
  - 2021-2023: Space qualification model (Phase C)
  - 2024-2025: flight model (Phase D)
- **2025: launch with Long-March CZ-7**
- **2025-2035: Science Operation**
- eXTP will be an observatory open to the worldwide science community (Core Programme + Guest Investigator Programme)

Orbit	550 km, <2.5° inclination
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%)

eXTP Time Frame



eXTP Science

- In support to the mission study, international working groups were preliminarily formed on the main science topics, preparing White Papers :
  1) **Accretion in Strong Field Gravity**
  2) **Dense Matter**
  3) **Strong Magnetism**
  4) Observatory Science
  5) Multi-Messenger Astronomy, Synergy with GWs

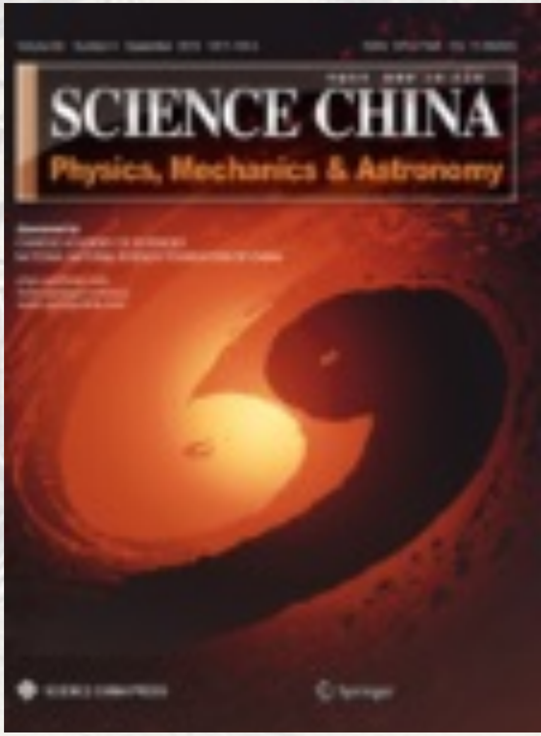
Core Science

eXTP will be both an experiment and an observatory

- In the framework of the ongoing joint China-Europe study, the preliminary working groups were further opened and expanded to interested scientists. Currently, a total of >260 scientists are contributing.

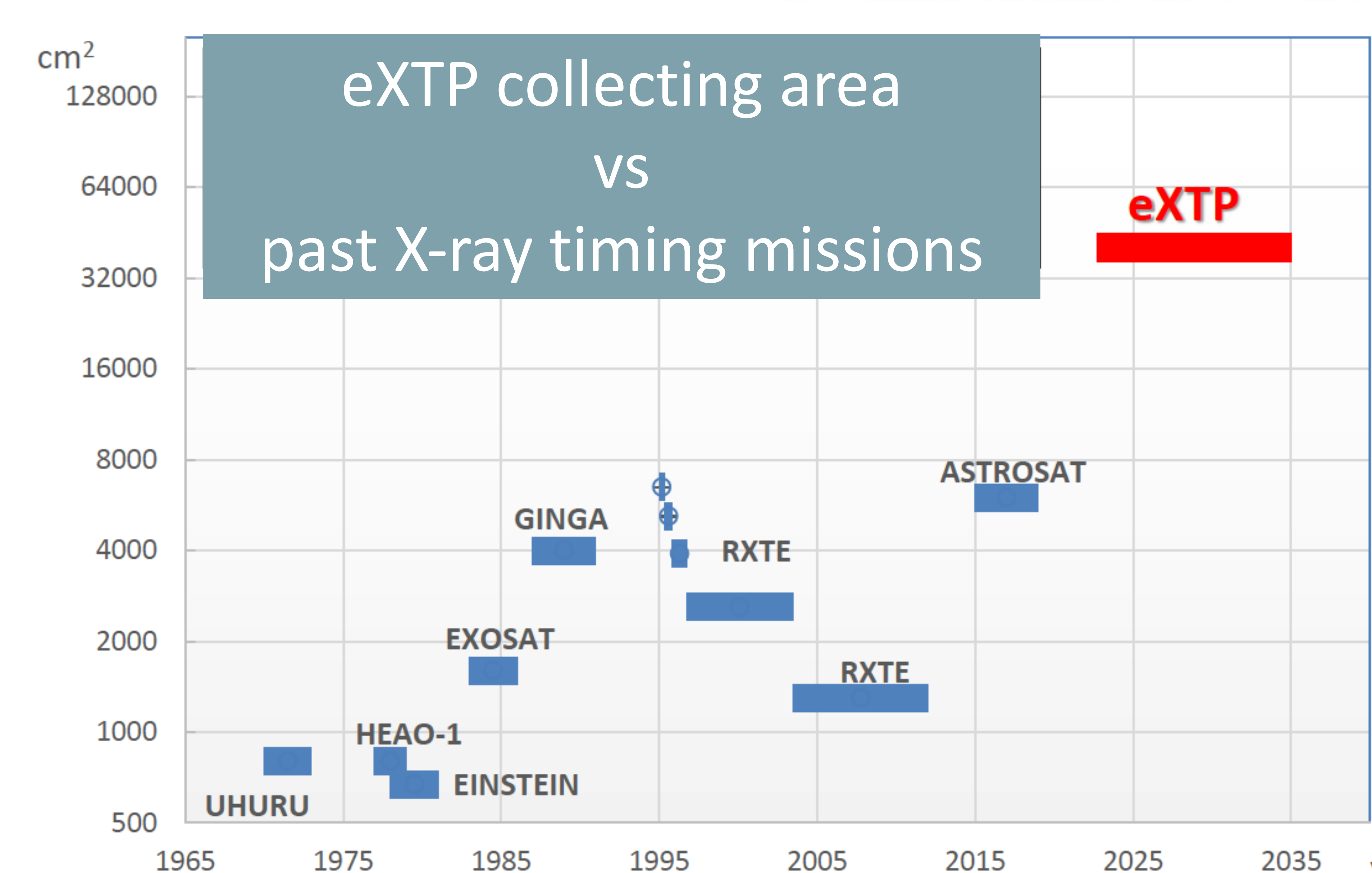
- More info at: http://www.isdc.unige.ch/extp/

- The eXTP WPs are expected to be published on a special issue of the Science China journal beginning 2018.



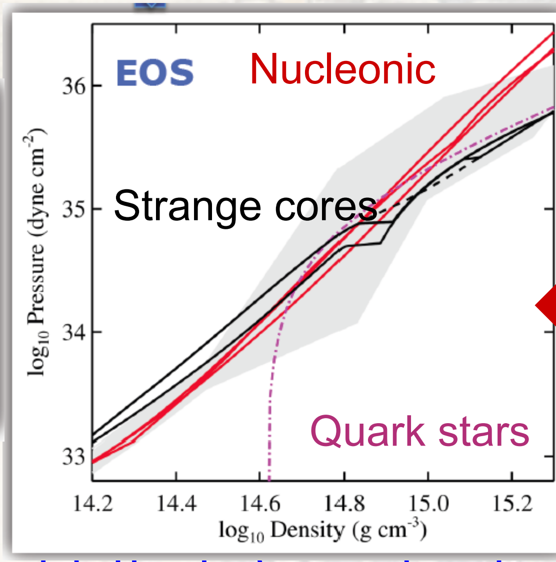
The enhanced X-ray Timing Polarimetry Mission

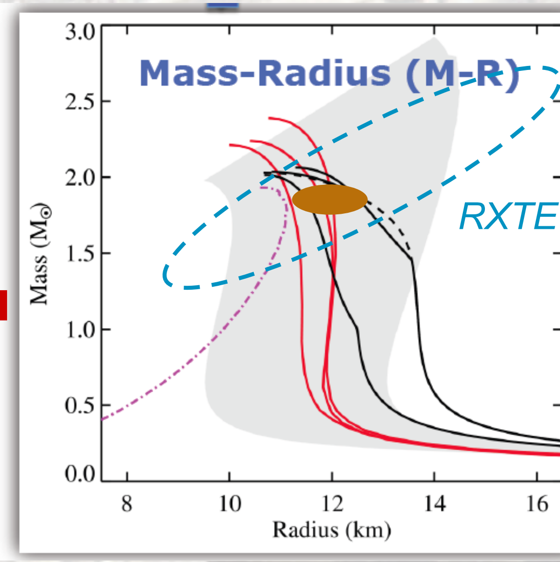
eXTP collecting area vs past X-ray timing missions



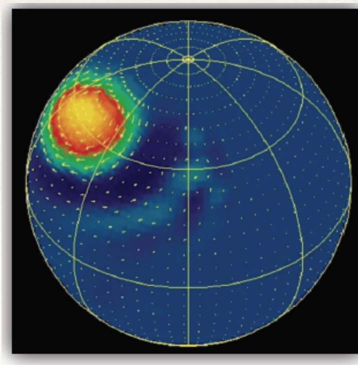
Ex. 1: Neutron Star EoS (Dense Matter)

- One goal is to study the EoS of ultradense matter in NS. This requires measuring the NS M,R to few %

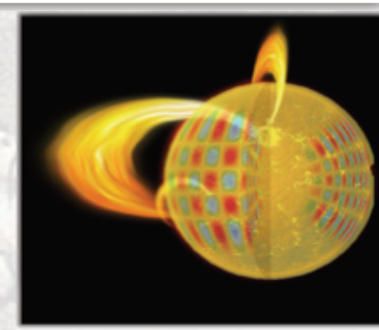




- Hot spots on the NS surface produce X-ray pulsations.

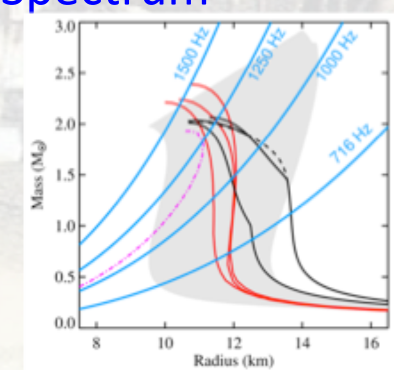


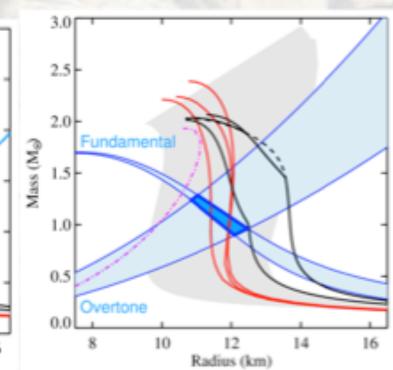
GR effects (light bending, *g*-redshift, etc.) encode information on M,R, recovered from the energy-dependent pulse profile.



- Starquakes on magnetars during flares produce seismic oscillations on the NS surface, seen in the Power Spectrum

  Oscillation mode encodes M, R information





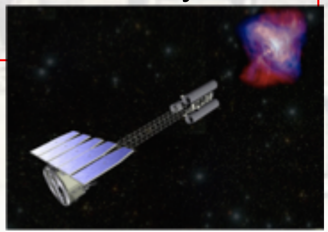
- Max NS rotation v (when V_{rot} at the R_{eq} equals the Keplerian V_{orb}) depends on M, R

The enhanced X-ray Timing Polarimetry Mission

	IXPE	XIPE	eXTP
MDP	1.8% (2×10^{-10} cgs) 300 ks	1.2% (2×10^{-10} cgs) 300 ks	1.3% (2×10^{-10} cgs) 300 ks
Bkg polarisation	<0.3%	<0.5%	<1%
Telescopes	3	3	4
Ang. resolution	28”	22”	30” (<15”)
FoV	12.9x12.9 arcmin^2	12.9x12.9 arcmin^2	12x12 arcmin^2
Effective Area	854 cm^2 @ 3 keV	1530 cm^2 @ 3 keV	600 cm^2 @ 3 keV
Spec. Resolution	16% @ 5.9 keV	16% @ 5.9 keV	16% @ 6 keV
Time Resolution	<100 μs	<8 μs	<100 μs
Energy Range	2-8 keV	2-8 keV	2-10 keV
Mission Duration	2+1 yrs	3+2 yrs	5 yrs (10)

Imaging X-ray Polarimetry Explorer (IXPE)

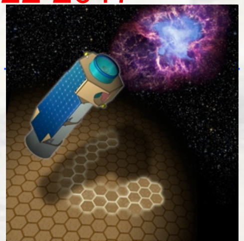
- **NASA** SMEX candidate (PI: M. Weisskopf)
- 175 M$
- Pre-selected in 2015 for Phase A study
- Selected as a SMEX mission in January 2017
- Launch Date: **2020**



X-ray Imaging Polarimeter Explorer (XIPE)

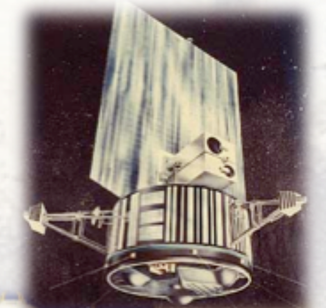
- **ESA** M4 candidate (PI: P. Soffitta)
- 450 M€
- Pre-selected in 2015 for Phase A study
- Down selection November 22 2017
- Launch Date: **2025**

ARIEL recommended by ESA but official decision Postponed till February 2018

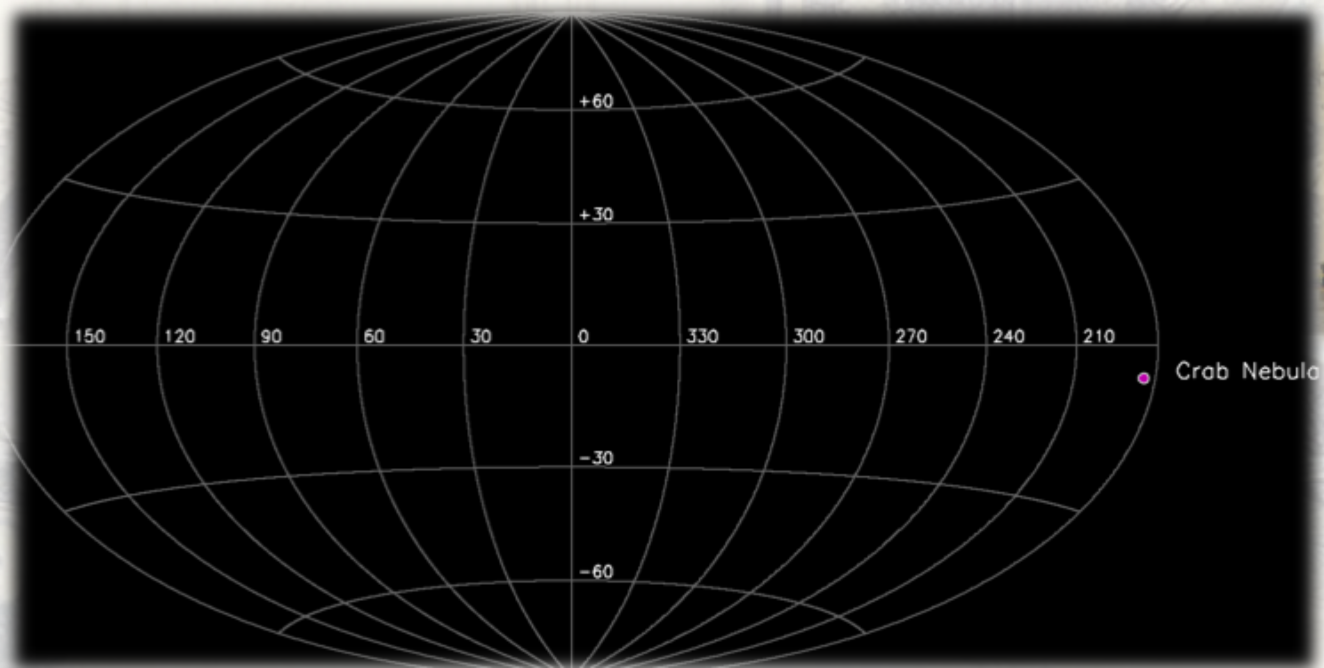


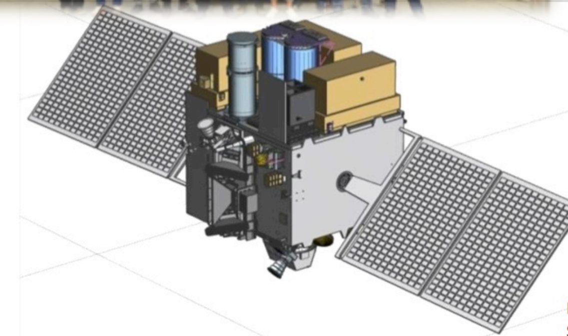
The Brief History of X-ray Polarimetry

- First X-ray polarisation measurement of the Crab Nebula: PD=15.4%±5.2% (5-20 keV) (Novick et al. **1972**)
- By *OSO-8:* PD=15.7%±1.5% @2.6 keV; after Pulsar subtraction: PD=19.2%±1.0% (Weisskopf et al. **1976**; **1978**)



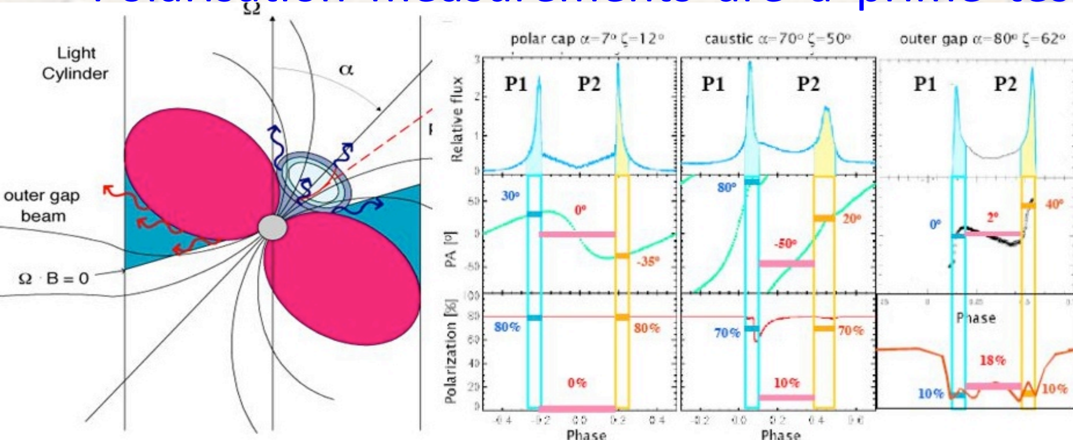
- PD=20.9%±5.0% (20-120 keV), Chauvin et al. (**2017**), *Pogo+*
- PD=32.7%±5.8% (100-380 keV), Vadawale et al. (**2017**), *Astrosat*

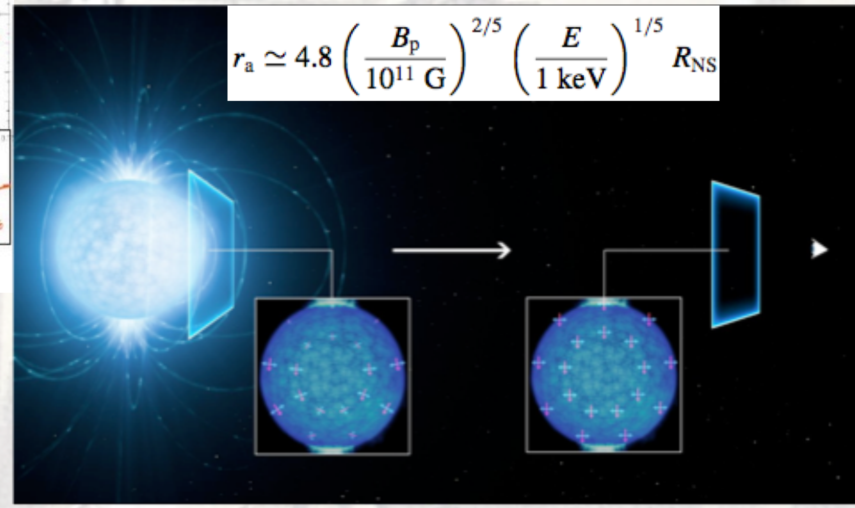




Ex. 2: Pulsar and Magnetar Polarimetry (Strong Magnetism)

- Polarisation measurements are a prime test for NS magnetosphere models and theory of radiation emission processes.

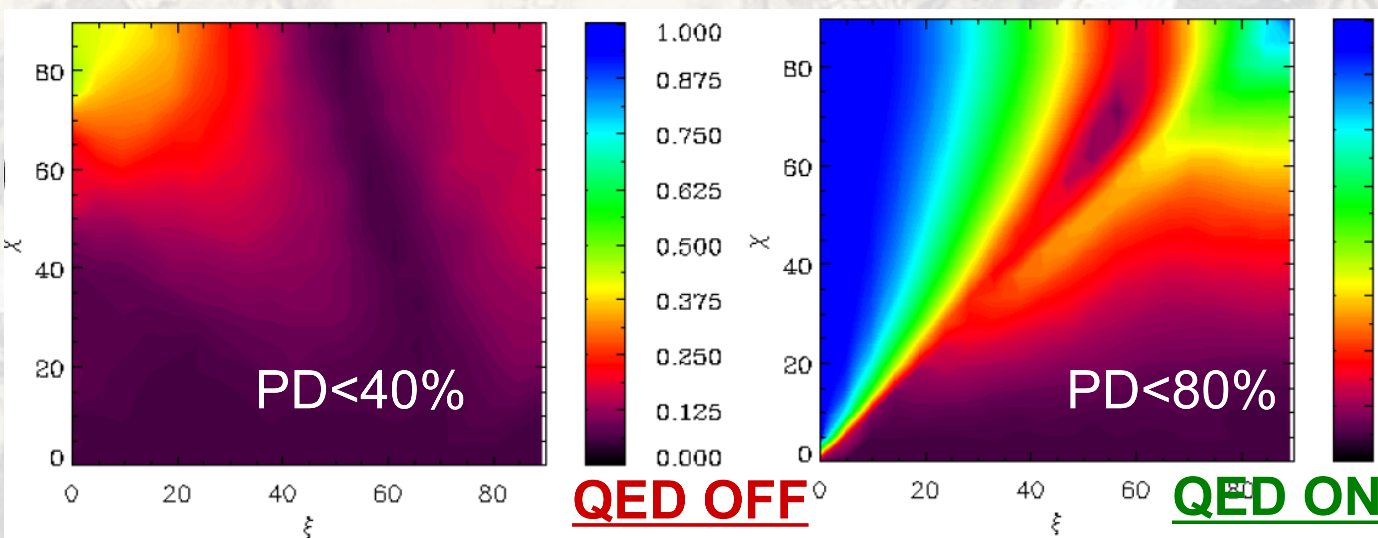


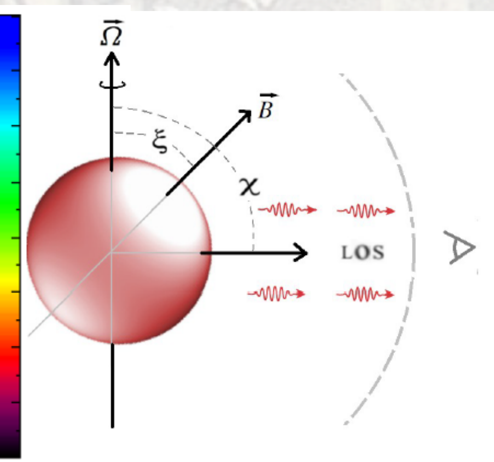


- Vacuum birefringence from VLT polarimetry of J1856.5-3754 (Mignani+2017).

  Too soft for X-ray polarimetry with eXTP.

  Magnetars are suitable sources, Harder thermal X-ray spectrum





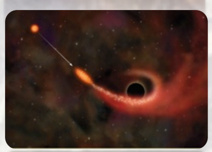
Taverna+ (2014;2017)

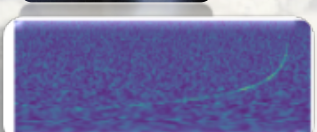
eXTP in Summary

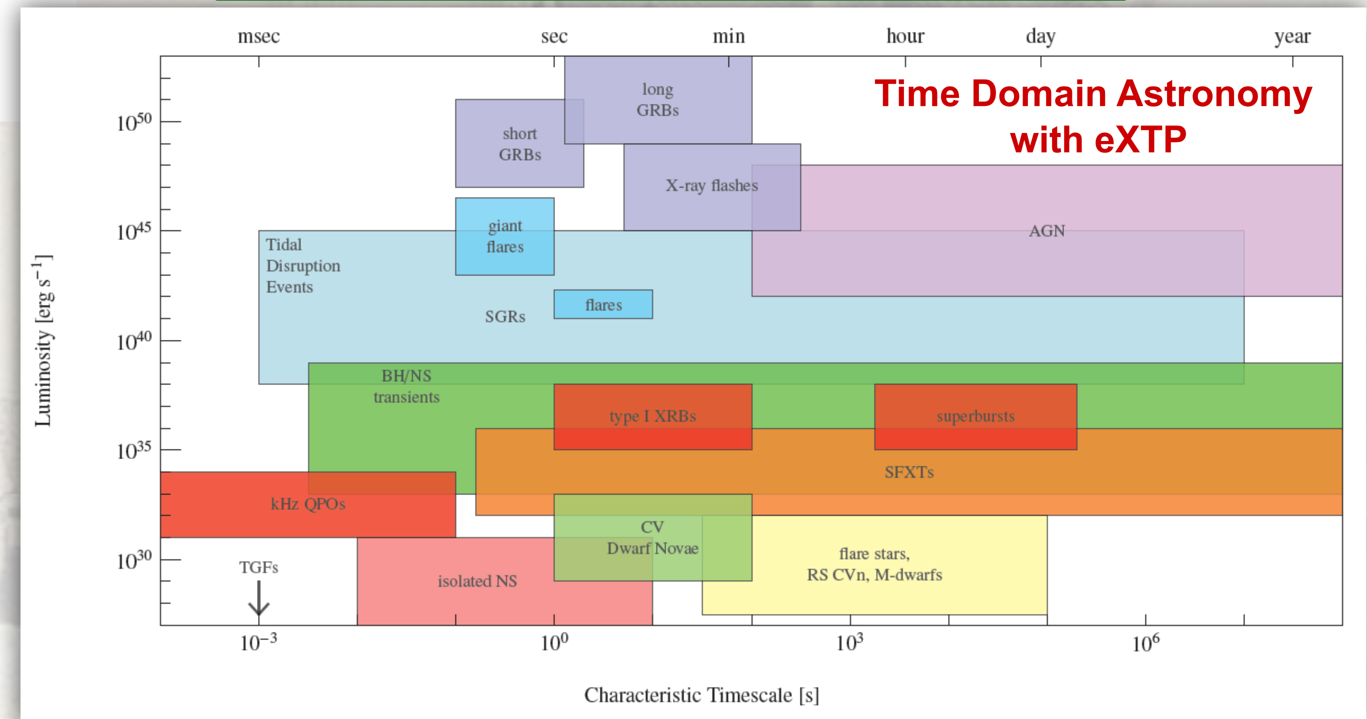
High time resolution X-ray timing
(LAD; <10μs), not possible with
ATHENA

X-ray polarimetry (PFA), sensitivity better than *IXPE* and comparable to *XIPE*

Phase-res X-ray spectroscopy
(LAD+SFA; <10μs) <250 eV,180 eV







Wide Field Monitoring
(WFM; 4 sr; 2-50 keV; <10μs)

http://www.isdc.unige.ch/extp/

Conclusions

- *eXTP* is conceived as an extremely powerful and general observatory for the study of X-ray sources

  - It is a **multi-task** telescope that will offer for the most complete diagnostics of compact sources: excellent **spectral**, **timing** and **polarimetry** sensitivity on a **single** payload
  - Experiment for **fundamental physics**: strong field gravity and dense matter
  - **Wide Range** of science goals. Study of Galactic/Extragalactic sources.
  - **Time Domain Astronomy** from ms to year time scales
  - Open a new window on the Universe (**Polarisation**)
  - **Synergy** with other observing facilities (MMA)

- *eXTP* is proposed as a cooperative effort between (at least) China and Europe.

European Contribution to X-ray Astronomy Missions

- ✓ XMM-Newton (1999) IASF
- THESEUS – ESA M5 candidate (>2025) IASF
- XIPE – ESA M4 (ex) candidate (2025) IASF
- ✓ ATHENA – ESA L2 approved (2028) IASF
- ✓ IXPE – NASA approved with participation from European Institutes (2021)
- ✓ eXTP – CAS approved (2025) IASF RPM, SM ***+ ?***

- **Together with *ATHENA*, *eXTP* is currently the only <u>approved</u> mission with both European contribution and <u>IASF participation</u>**

Should we do more?

Studio di
Astrofisica delle Alte Energie
e di Fisica Astroparticellare

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ASTROPHYSICS HIGH ENERGY AND ASTROPARTICLE PHYSICS STUDY

Accordo Attuativo ASI-INAF n. 2017-14-H.0)

Analisi Dati, Teoria e Simulazioni

Assegnazioni finanziarie primo bando "Analisi Dati, Teoria e Simulazioni"

Coordinatore	Proposta Nr.	Titolo	Finanziamento (kEuro)
Stefano Andreon	ADTS-07	The X-ray complete census of all massive clusters in 1/16th of the sky.	5
Tomaso Belloni	ADTS-21	High-Energy observations of Stellar-mass Compact Objects: from CVs to Ultraluminous X-Ray Sources.	101
Mario Edoardo Bertaina	ADTS-18	Search for Extreme Energy Cosmic Rays and nuclearites with TUS satellite.	26
Pasquale Blasi	ADTS-23	A Modern Approach to Cosmic Ray Transport in the Galaxy.	50
Massimo Cappi	ADTS-29	Probing AGN feedback in the most luminous QSOs at cosmic noon (z~2-3).	80
Andrea De Luca	ADTS-04	Understanding the x-ray variabLe and Transient Sky (ULTraS).	80
Alessandra De Rosa	ADTS-09	Scientific Simulations for the enhanced X-ray timing polarimetry mission eXTP. [130]	32
Fiorenza Donato	ADTS-25	Astronomy with charged leptons: the new frontier for Galactic sources.	7
Stefano Ettori	ADTS-13	Galaxy clusters in X-rays: the buildup of massive structures in the last 10 Gyrs.	60
Gabriele Ghisellini	ADTS-20	Gamma Ray Bursts: multi-messenger cosmic lab and cosmic probes.	30
Francesco Massaro	ADTS-05	Softly X-raying the extragalactic γ-ray sky.	5
Marina Orio	ADTS-08	The high resolution X-ray grating spectra of novae in outburst and persistent supersoft sources.	20
Salvatore Orlando	ADTS-11	Connecting supernova remnants to their progenitor supernovae by combining three-dimensional magnetohydrodynamic simulations and analysis of high energy observations.	10

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