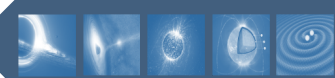# XRO – X-RAY OBSERVATORIES (A.K.A. EXTP & IXPE)

RICCARDO CAMPANA

INAF/OAS & INFN/BOLOGNA, ITALY

ASSEMBLEA DI SEZIONE – 4 FEBBRAIO 2020

- Nuova sigla in CSN2

- Riunisce le attività sulle missioni IXPE (già in CSN2) ed eXTP (nuova)

- Responsabili nazionali: L. Baldini (PI) e V. Bonvicini (TS)

- Strutture partecipanti: TS/UD, PI, TO, RM2, MI, PV, BO, TIFPA

- ~25 FTE complessivi

- Convergenza su sigla unica per affinità obiettivi scientifici, sviluppi tecnologici e larga sovrapposizione del team (IXPE e Polarimetry Focusing Array di eXTP).

- L'attività di **Bologna** coinvolge **eXTP** (responsabile locale G. Baldazzi)

- L'anagrafica di Bologna è composta da 1.9 FTE complessivi.

- I costi vivi dello sviluppo di entrambe le missioni sono supportati dall'ASI. Richieste finanziarie in CSN2 molto limitate in questa fase.
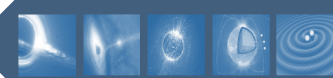
❑ A **flagship X-ray observatory** mission, being developed by the Chinese Academy of Sciences, with a large contribution by a European Consortium inherited from the ESA-M3 LOFT mission study. ESA is studying a MoO participation.

❑ Currently at the start of its **Phase B**. The launch date is planned in 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.
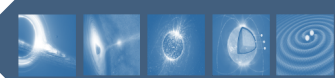
Study of **matter under extreme conditions** of gravity, density and magnetism. For the first time: simultaneous, high-throughput spectral, **timing** and **polarimetry** observations.

➢ 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.
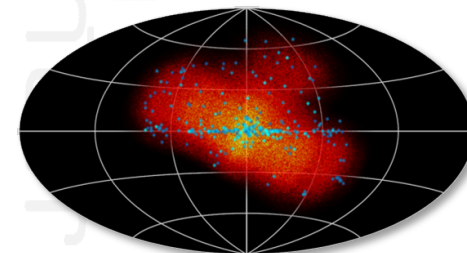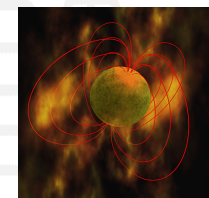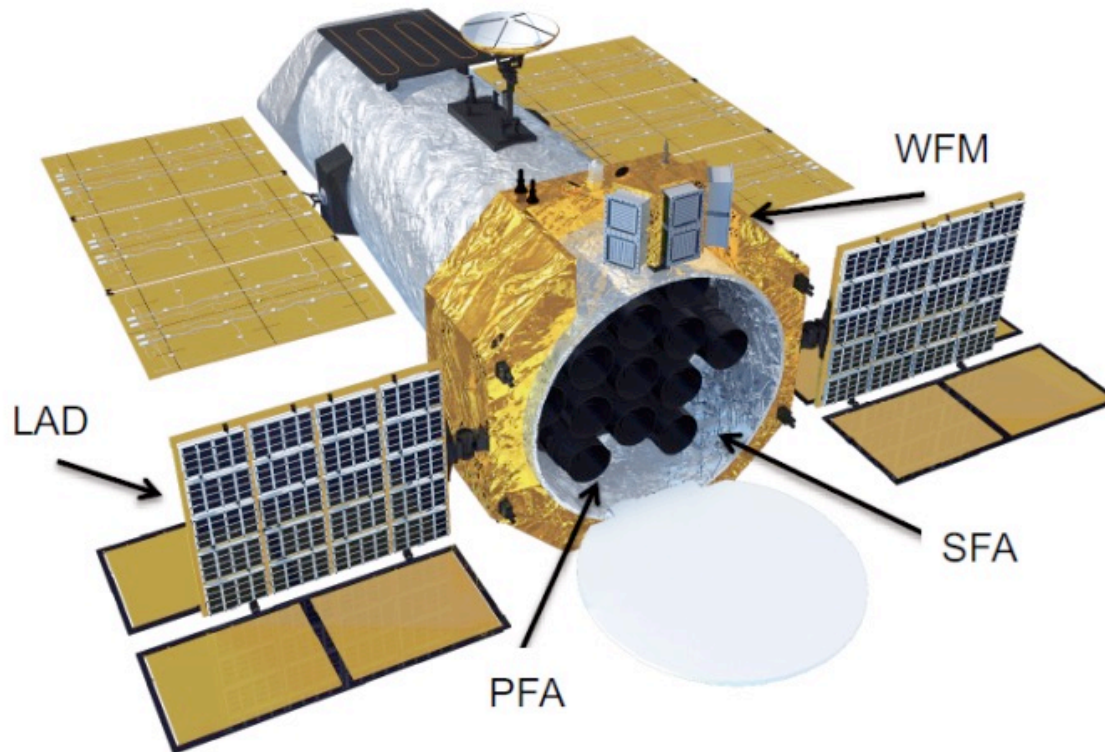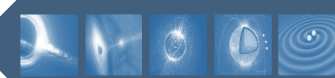
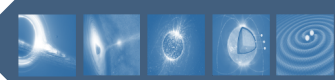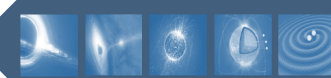| Payload	Configuration	Optics	Detector
SFA	9 Telescopes	Nickel replica	SDD
LAD	40 Modules	MCP Collimator	SDD
PFA	4 Telescopes	Nickel replica	GPD
WFM	6 Cameras	1.5 Coded Mask	SDD

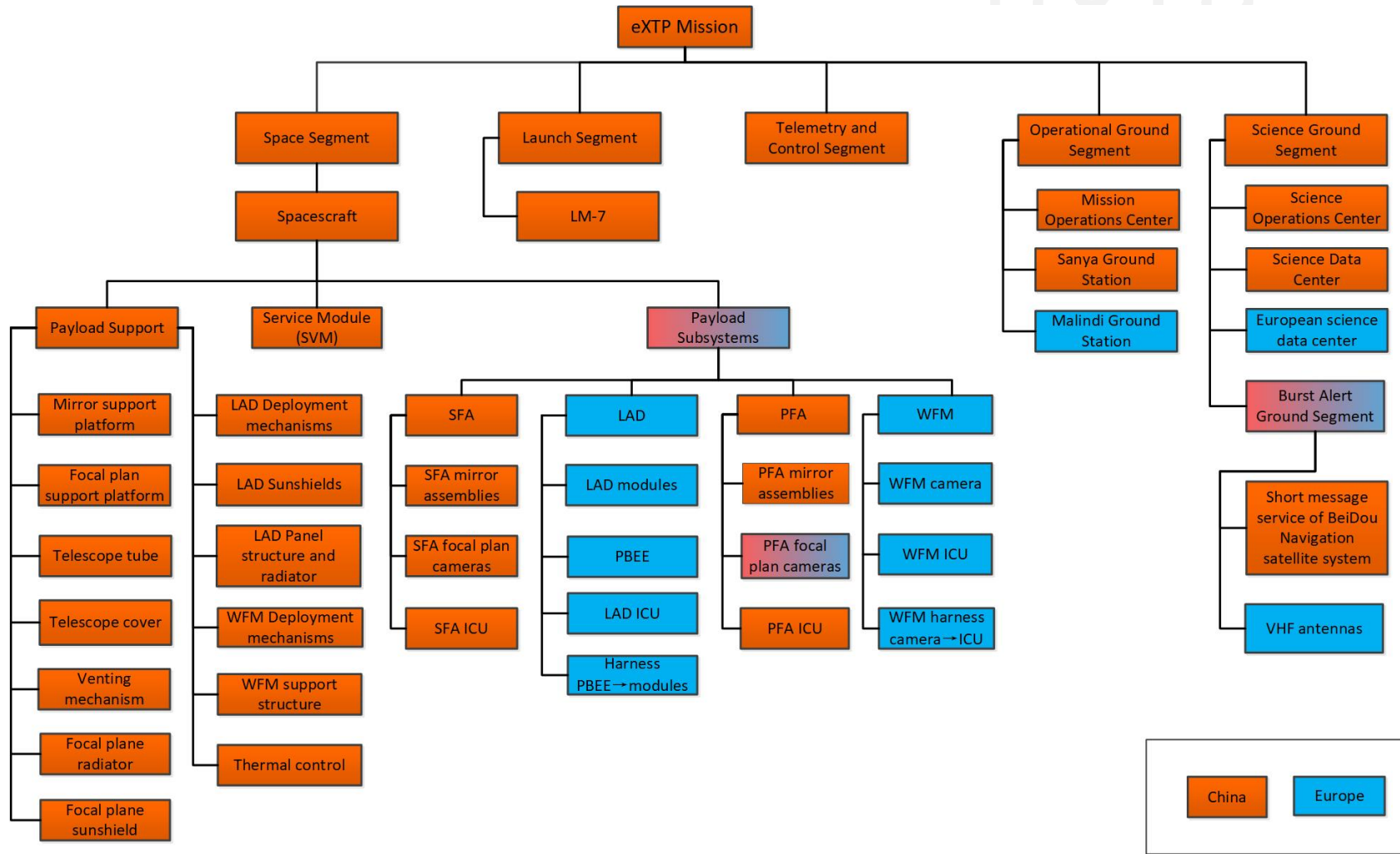| Parameter	Value
Orbit	550 km, <2.5° inclination
Launcher	Long-March CZ-7 + upper stage, from Wenchang
Mass	4500 kg
Power	3.6 kW
Telemetry	3.2 Tb/day (X-band)
Ground Stations	Sanya, Malindi
Pointing	3-axis stabilized, < 0.01° (3-sigma)
Sky visibility	50% (goal 75%)
Mission Duration	5 years (goal 8 years)
Launch date	2027

eXTP PI Institute:
IHEP/CAS, Beijing

CAS

CNSA

IHEP Beijing

Tsinghua University

Tongji University

CAST Beijing

Microsat Shanghai

Italy

Spain

Germany

France

Switzerland

Czech Republic

Poland

Denmark

The Netherlands

eXTP Mission

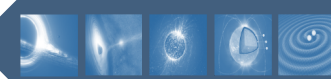- **Space Segment**
  - **Spacescraft**
    - **Payload Support**
      - Mirror support platform
      - Focal plan support platform
      - Telescope tube
      - Telescope cover
      - Venting mechanism
      - Focal plane radiator
      - Focal plane sunshield
    - **Service Module (SVM)**
      - LAD Deployment mechanisms
      - LAD Sunshields
      - LAD Panel structure and radiator
      - WFM Deployment mechanisms
      - WFM support structure
      - Thermal control
    - **Payload Subsystems**
      - **SFA**
        - SFA mirror assemblies
        - SFA focal plan cameras
        - SFA ICU
      - **LAD**
        - LAD modules
        - PBEE
        - LAD ICU
        - Harness PBEE→modules
      - **PFA**
        - PFA mirror assemblies
        - PFA focal plan cameras
        - PFA ICU
      - **WFM**
        - WFM camera
        - WFM ICU
        - WFM harness camera→ICU
- **Launch Segment**
  - LM-7
- **Telemetry and Control Segment**
- **Operational Ground Segment**
  - Mission Operations Center
  - Sanya Ground Station
  - Malindi Ground Station
- **Science Ground Segment**
  - Science Operations Center
  - Science Data Center
  - European science data center
  - Burst Alert Ground Segment
    - Short message service of BeiDou Navigation satellite system
    - VHF antennas

Legend:
- China
- Europe

enhanced x-ray timing and polarimetry mission **eXTP**

❖ Total effective area: 3.4 m² @8 keV

❖ Energy band: 2-30 keV

❖ Energy resolution: <240 eV FWHM @6 keV

❖ Based on the LOFT/LAD design

❖ 40 Modules on support panels

❖ 1° Collimated, large-area SDD detector. Single photon, <10μs

eXTP
enhanced x-ray timing and polarimetry mission
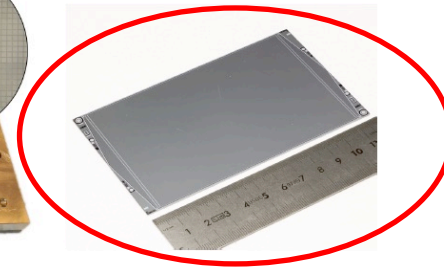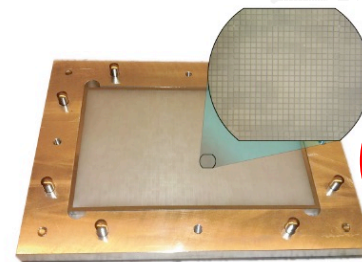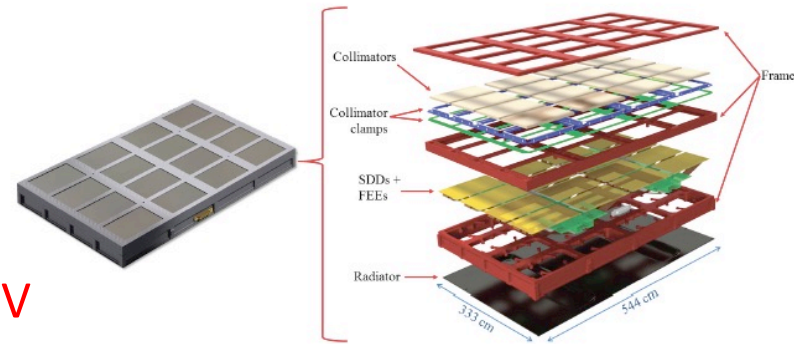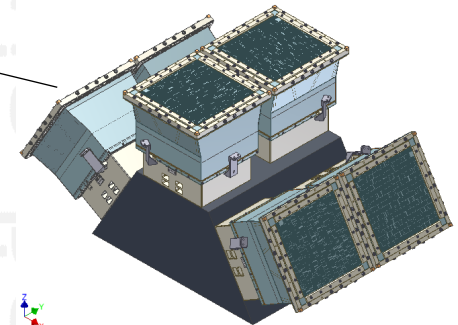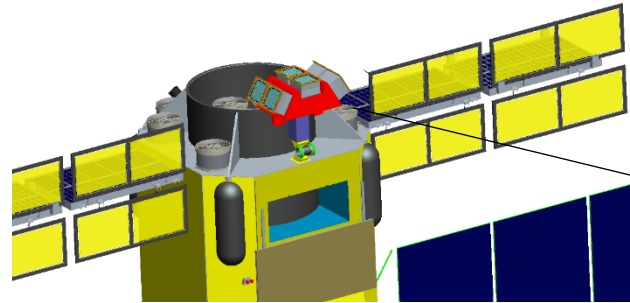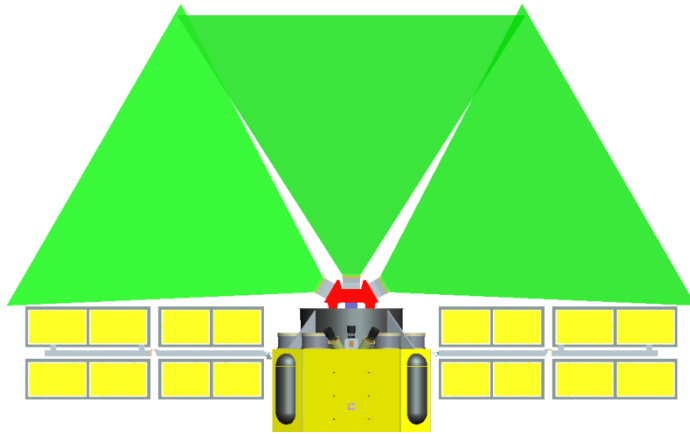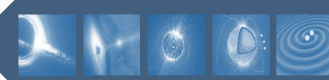
- ❖ Field of View: 4 steradian (at 20% response)

- ❖ 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)

- ❖ Same design as LOFT/WFM, 3 units (6 cameras)

- ❖ Same detectors as LAD (SDD). Single photon, <10μs

Soft Response

Large area

Polarization

Monitoring
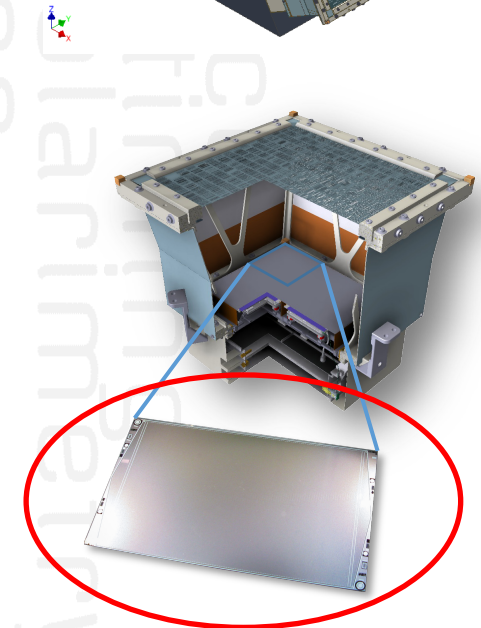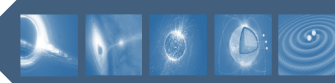
Payload	Parameter	Specification
SFA	Energy range	0.5-10 keV
	Effective area	>7000 cm^2 @1 keV, >5000 cm^2 @6 keV
	Energy resolution	<180 eV FWHM @6 keV
	FoV/HPD	12 arcmin / 1 arcmin
	Focal plane detector	Pixelated SDD (19 pixels)
LAD	Energy range	2-30 keV (extended: 30-80 keV for out-FoV)
	Effective area	34000 cm^2
	Energy resolution	<240 eV FWHM @6 keV
	FoV	1° (FWHM)
	Detector	Large area SDD (640 units, 40 Modules)
PFA	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	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
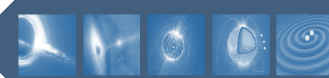
Effective Area of SFA and LAD
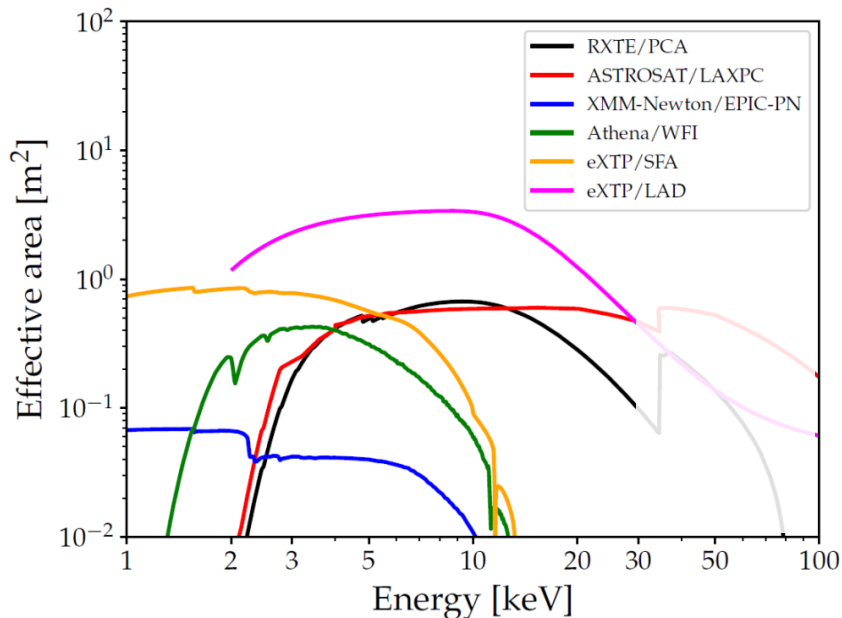
Simultaneous FoV of WFM
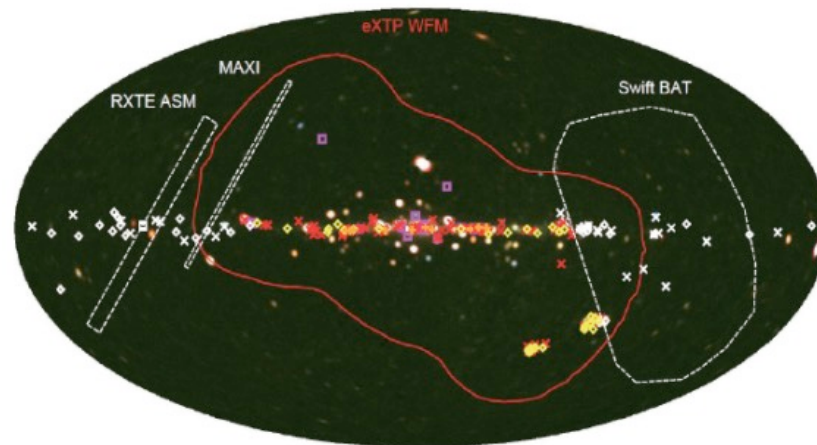
❖ **LAD:**   6x RXTE/PCA, 35x XMM-Newton (*but collimated*!) + hard-X response

❖ **SFA:**   8x XMM-Newton and 0.3-2x Athena/WFI (*but multiple optics and larger PSF*!). Limiting sensitivity ~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

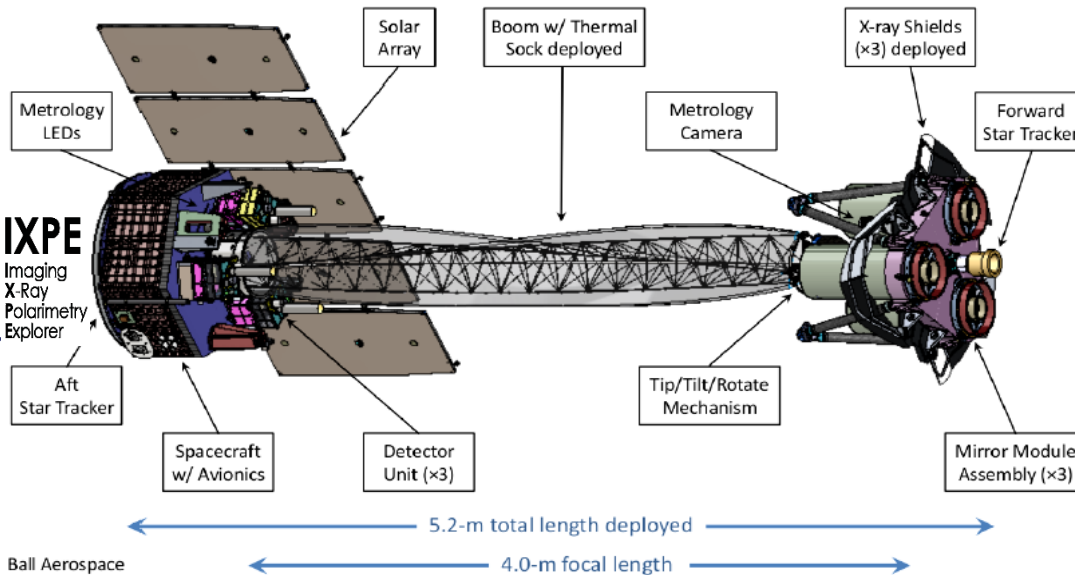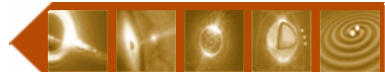Solar Array · Boom w/ Thermal Sock deployed · X-ray Shields (×3) deployed · Metrology LEDs · Metrology Camera · Forward Star Tracker · Aft Star Tracker · Spacecraft w/ Avionics · Detector Unit (×3) · Tip/Tilt/Rotate Mechanism · Mirror Module Assembly (×3)

5.2-m total length deployed
4.0-m focal length
Ball Aerospace

PI Dr. Martin Weisskopf (NASA Marshall Space Flight Center, MSFC, Huntsville, Alabama, USA).
▪ Ball Aerospace (Broomfield Colorado): spacecraft and mission integration.
▪ ASI: funds pol. detectors units (DU), built and calibrated by INFN (Pisa, Torino) and INAF-IAPS.
▪ MSFC: grazing-incidence X-ray mirrors (Brian Ramsey leads).

▪ NASA's Small Explorer (SMEX) mission $188 million (includes launch vehicle, operations, data analysis costs). NASA selection on Jan. 3, 2017.
Before IXPE 12 proposals of polarimetry detectors for X-ray satellites since 1988 (XMM).
2001: gas pixel detector (GDP) technology established as optimal for for X-ray polarim.
▪ Pointing telescope, first time exploration of hidden details of violent and dense astronomical objects (extreme gravitational, electric, magnetic fields): Stellar/supermassive accreting BHs, neutron stars (NS), pulsars (PSR), magnetars, supernova remnants (SNR), white dwarf (WD) stars, Sgr A* , radio-quiet/loud AGN.
▪ 3 identical telescopes and cameras: imaging (energy, timing, spatial res.) and polarimetry in 2-8 keV band. Polarization-sensitive detector + grazing-incidence optics for each one. INFN responsibility: polarization-sensitive gas-pixel detectors (GPD), readout electronics, housing, participation to tests and science (simulations, post-launch data analysis).
▪ 2-year baseline mission (famous/bright X-ray sources, secure pol data for science), + 1 year extension (room for low-pol obj. & fundamental physics).

Polarization sensitivity (MDP)	<5.5 % for 1x10^{-11} erg/s/cm^2 (10 days observation)
or (MDP)	1% for 10 mCrab (300 ks)
Spurious modulation	< 0.3 %
Energy band	2-8 keV
Number of telescopes	3
Angular resolution	< 30"
Field of view	12.9 x 12.9 arcmin2 (10 arcmin overlapping)
Focal length	4 meters
Effective aera at 3 keV	700 cm^2
Spectral resolution	< 25 % @ 5.9 keV
Timing accuracy	20 us (Using GPS)
Dead time	1.2 ms
Operational phase	2 yr + extension (1 yr)
Sky coverage, orbit	25 %
Orbit	LEO 600 km (0.1º inclination)
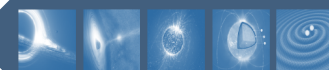
Ricercatori						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	**Baldazzi Giuseppe**		Associato	Ricercatore Universitario	CSN III	40
2	**Fuschino Fabio**		Associato	Ricercatore Confermato (Ricercatore)	CSN II	50
3	**Virgilli Enrico**		Associato	Ricercatore Confermato (Ricercatore)	CSN II	50
			Numero Totale Ricercatori	3	FTE: 1.40	

Tecnologi						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	**Campana Riccardo**		Associato	Tecnologo		50
			Numero Totale Tecnologi	1	FTE: 0.50	

eXTP
enhanced x-ray timing
and polarimetry mission
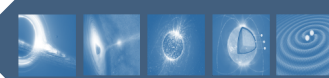
❑ Hardware:

- ▪ Supporto sviluppo e test rivelatori LAD e WFM
- ▪ Sviluppo Detector Assembly WFM
- ▪ Calibrazioni LAD e WFM (Detection Plane)
- ▪ Simulazioni Monte Carlo/Geant4 delle performance scientifiche e del background in orbita

❑ Scienza:

- ▪ Supporto alle simulazioni scientifiche
- ▪ Partecipazione ai working group scientifici