The mini X-ray Imaging Polarimetry Explorer (mXIPE)

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Abstract

The mini X-ray Imaging Polarimetry Explorer (mXIPE) is dedicated to the measurement of X-ray polarization of celestial sources in the 2-8 keV energy range. The mission is an evolution of the XIPE mission, which was proposed to the ESA Small Mission Call in 2012. At that time the mission was not selected because it was judged scientifically interesting but too complex for the cost cap of the call; for this reason, we are proposing a significantly simplified payload which however can still tackle the most important scientific goals of the original XIPE. A single imaging photoelectric polarimeter, based on the mature Gas Pixel Detector design (TRL of 6 on the ISO scale) is in the focus of an X-ray telescope of modern conception, which allows for a larger area with a by far smaller mass with respect to the two JET-X telescopes proposed originally. This allows mXIPE to be fully compliant to the boundary conditions of the ESA-CAS call.

X-ray polarimetry in Astrophysics

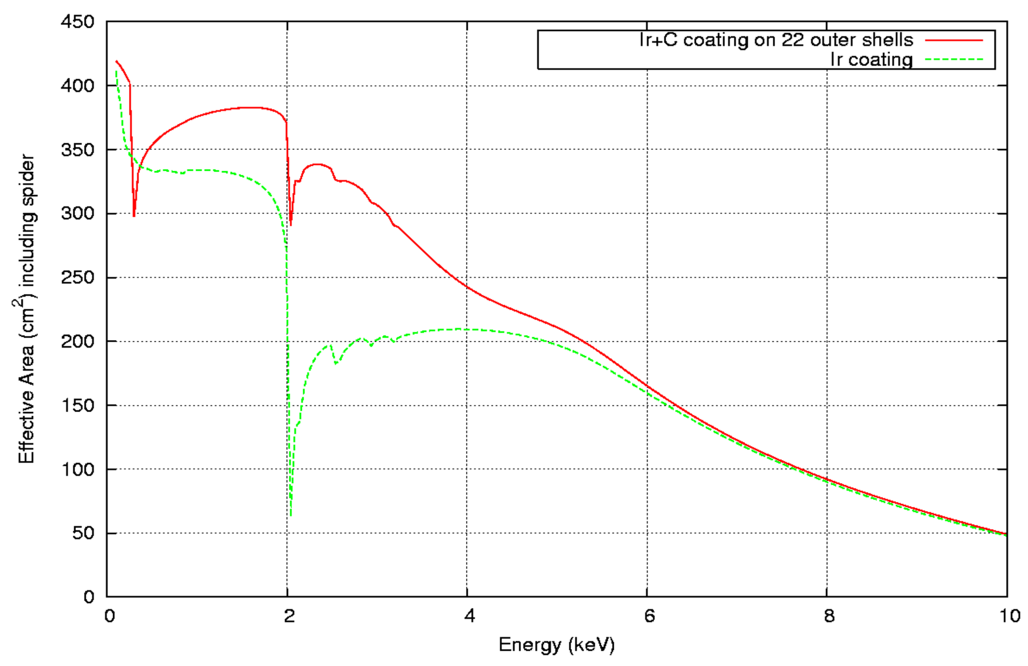
X-ray polarimetry is expected to produce a significant step forward in the understanding of what happens in the sites of **acceleration of particles** such as pulsar wind nebulae, shell-like supernova remnants, jets in microquasars and blazars. It is also expected to give important results in the study of **matter in extreme conditions**, providing a measurement of the spin of black holes , the orientation of magnetic field versus rotation axis in magnetized neutron stars and an indication of its strenght. Polarimetry can also be a powerful tool to test theories of **fundamental Physics** by using cosmic scenarios as a laboratory. Beside testing General Relativity and Quantum Electrodynamics in extreme gravitational and magnetic fields, can provide a tool to test phenomenologies foreseen by some theories of Quantum Gravity and of axion-photon coupling.

The mXIPE mission

mXIPE has a standard mission profile and its payload is based on mature items:

Classical grazing incidence optics, designed specifically for the mXIPE mission with a 2.1 m focal length. The use of an Iridium/Carbon coating allows to reach a collecting area of 300 cm² at 3 keV.

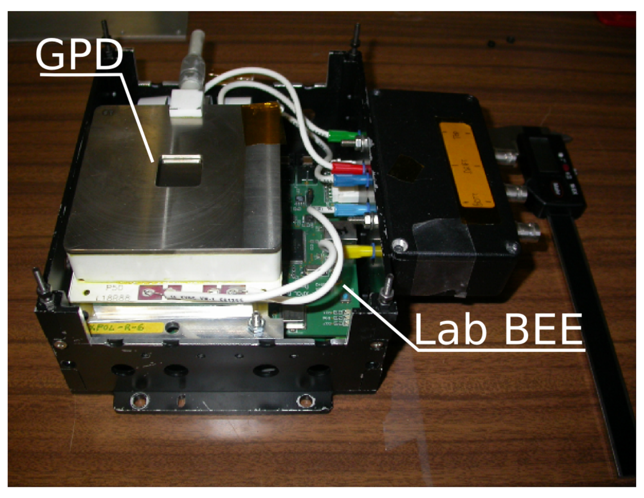
Focal length: 2.1 m
Num. of shells: 30
Diameter: 9-27 cm
Weight: 20.4 kg



Effective area of the mXIPE telescope

Gas Pixel Detector, deeply studied for the XEUS/IXO mission under ESA supervision (TRL of 6 in the ISO scale). The GPD is able to measure the linear polarization of absorbed photons by reconstructing the emission direction of emitted photoelectrons in a gas mixture. It also provides event by event a:

Spectral resolution: 16% @ 5.9 keV
Spatial resolution: ~ 100 um HEW
Time resolution: ~ 8 us



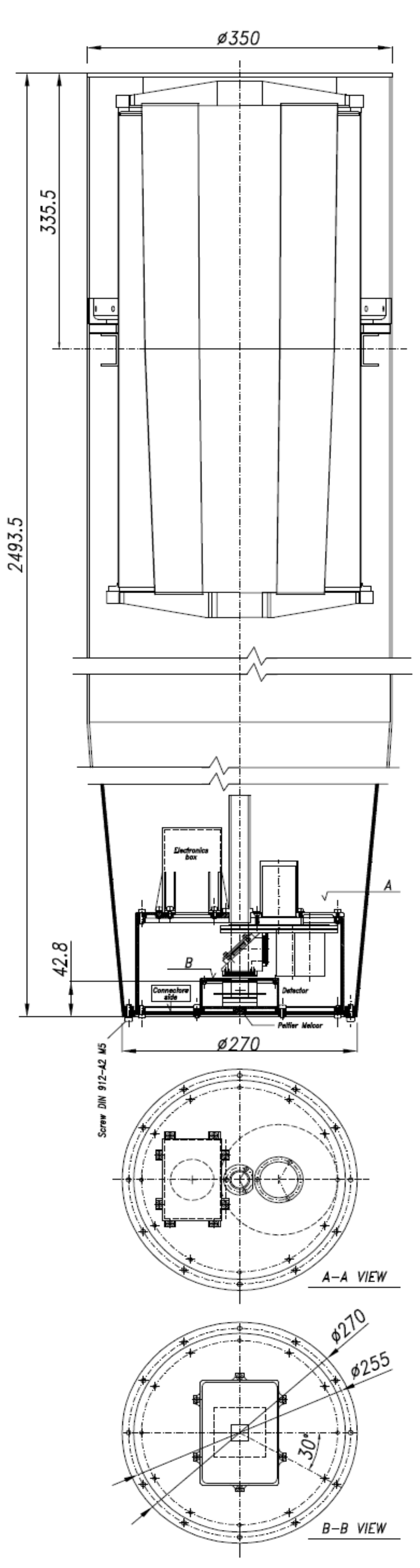
The current GPD prototype

mXIPE payload

A sketch of the mXIPE payload, which is composed of the X-ray telescope and focal plane GPD, is on the left. It is enclosed in a cylinder 2.5 m long and with a diameter of 35 cm. A filter wheel with filters and calibration sources is in front of the detector. A preliminary mass and power budget for the payload is:

Item	Mass (kg)
Detector (including HV) + Filter wheel + box	6.7
Control electronics + Memory	4.0
Mirror module	33.8
Supporting tube	11.0
Support flange	4.2
TOTAL	**59.7**

Item	Power (W)
Detector (including HV)	3.5
Peltier cooler for GPD temp control	1.2
Control electronics + Memory	12
Mirror heaters	20
TOTAL	**36.7**



mXIPE facts

- **Mission profile**
  Orbit: Low Earth Equatorial Orbit (preferentially)
  Accessible sky: 90°+/-30° from Sun direction
- **Launcher** Long March or Vega
- **Telemetry** (typical): <41 kbit/s
- **AOCS requirements** Pointing accuracy/stability: a few arcmin, post facto reconstruction 10''
- **Spacecraft** Compatible with many small size busses

mXIPE science

Science requirements

Polarization sensitivity	MDP = 12.6% in 100ks for 1 mCrab
Imaging capability	About 30'', 28x28 arcmin² field of view
Spectral resolution	16% @ 5.9 keV
Timing	Resolution 8 us, 10 us dead time, negligible for all observations
Mixture	20%He-80%DME 1 atm 1 cm
Energy range	2-8 keV
Background	2x10^{-7} c/s or 2 nCrab
Systematic effects	<1%

Science objectives: a few examples

Acceleration phenomena: XIPE can measure a Minimum Detectable Polarization at 99% confidence level of 2% in 5x5 angular resolved regions of the Crab Nebula in one day observation (100ks). Also a few other young PWNe will be accessible, exploring similarities and differences with respect to Crab. With a 1 Ms observation, angularly and energy-resolved polarimetry at the level of a few percent of Cas-A is possible; about 10 other SNRs have a sufficient small size (< mXIPE FoV) and flux for detecting polarization. mXIPE can reach a MDP of a few percent in a few days observations for some of the brightest blazars. For example, an MDP of <3% can be reached for Mrk421 in 4x10^{5}s. Several bright intermediate polars, and certainly the brightest polar, AM Her, when in high state, can be searched for phase-dependent polarization. In the latter case, an MDP of 6% can be reached in 10 phase bins with 1Ms observation. In the case of NGC1068, an MDP of 3.8% can be reached with an observation lasting 500 ks, allowing to test the geometry of the circumnuclear matter.
Matter in extreme conditions & Fundamental Physics: A few pulsars other than the Crab and a few Magnetars, like the Anomalous X-ray Pulsars (AXP) 4U 0142+614 (MDP of 6% in 5 phase bins and 2 energies with 1Ms observation) and the Soft Gamma Repeaters SGR1900+14 (MDP of 13% in 5 phase bins 2 energies in 1Ms when in quiescence), can be looked at to start searching for QED effects.
Regarding black hole spin measurements, the best but not the only source to search for Strong Gravity effect on X-ray polarization is GRS1915+105 because of the high inclination. Other less inclined, but still bright, sources may show lower polarization levels, which however could still be easily detected.

The mXIPE team

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