IXPE: The Imaging X-ray Polarimetry Explorer

Implementing a Dedicated Polarimetry Mission

Brian Ramsey and the IXPE team

Challenge

- Only a few experiments have conducted x-ray polarimetry of cosmic sources since Weisskopf et al confirmed the 19% polarization of the Crab Nebula with the Orbiting Solar Observatory (OSO-8) in the 70's
- The challenge is to measure a faint polarized component against a background of non-polarized signal (as well as the other, typical background components)
- Typically, for a few % minimum detectable polarization, 10^6 photons are required.
- So, *a dedicated mission is vital* with instruments that are designed specifically to measure polarization (with minimal systematic effects)

Opportunity

DRAFT 2014 SMEX AO

National Aeronautics and Space Administration

NNH14ZDA011J **Release Date July 14, 2014**

DRAFT Announcement of Opportunity

Astrophysics Explorers Program

2014 Small Explorer (SMEX)

Comments Due Date: **August 4, 2014**

OMB Approval Number 2700-0085

- NASA releases its draft announcement of opportunity for small explorer missions
- Proposal are expected to be due early next year (~ Jan 2015)
- The IXPE team will be proposing a dedicated polarimetry mission

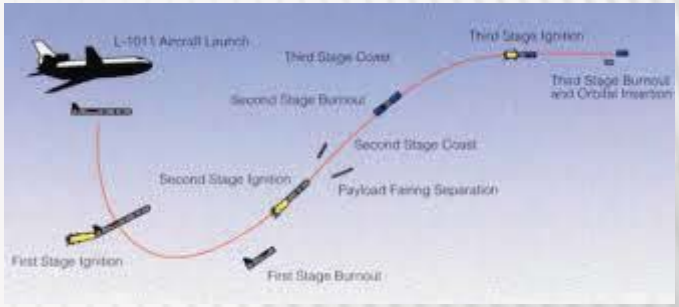
Opportunity

Pegasus launched

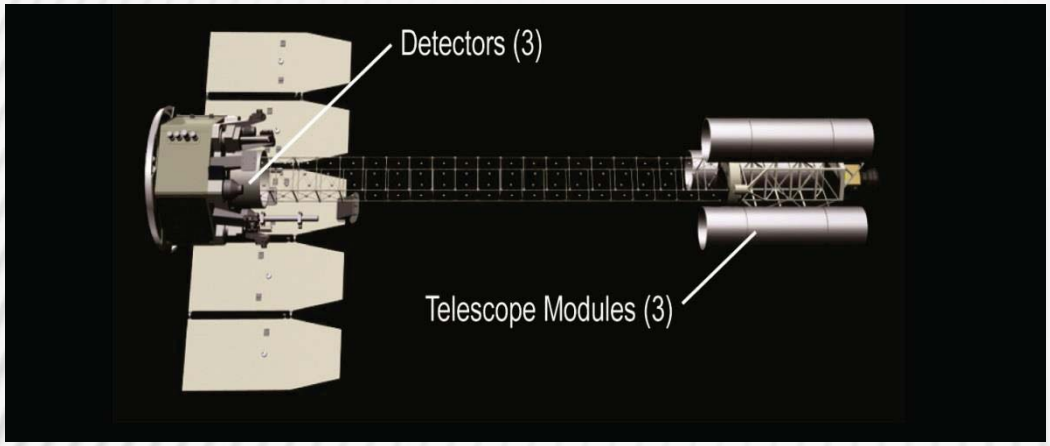
~ 1-m diameter x 2 m long payload capability

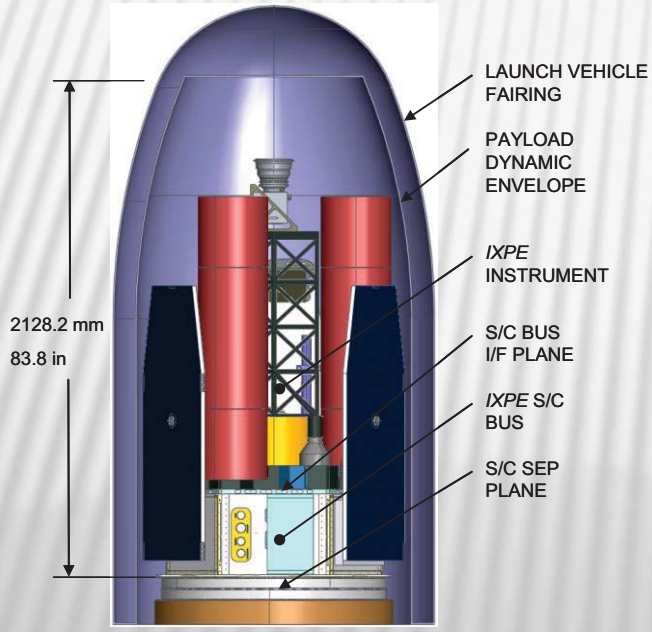
~ 300 kg capability for payload + satellite bus

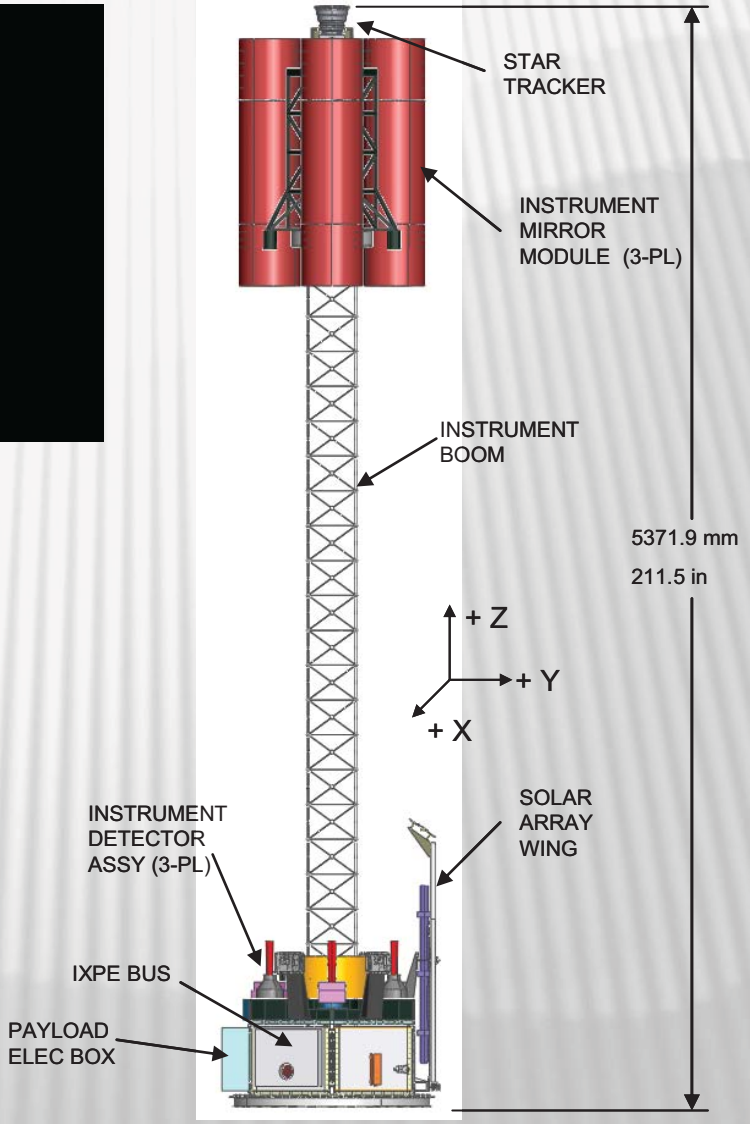
$125M total including contingency



IXPE Realization







IXPE Payload

Optics
NASA/MSFC

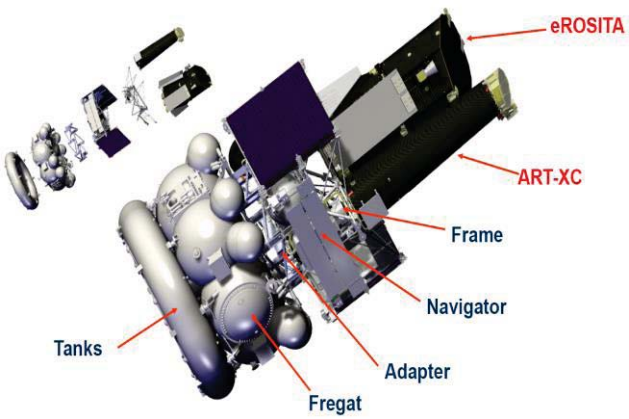
Type	Electroformed nickel/cobalt
Number of telescopes	3
Shells per telescope	30
Inner shell diameter	274 mm
Outer shell diameter	142 mm
Type	Electroformed nickel/cobalt
Angular resolution	25 arcsec HEW
Focal length	4 m
Peak effective area	~ 1000 cm^2 (3 modules)

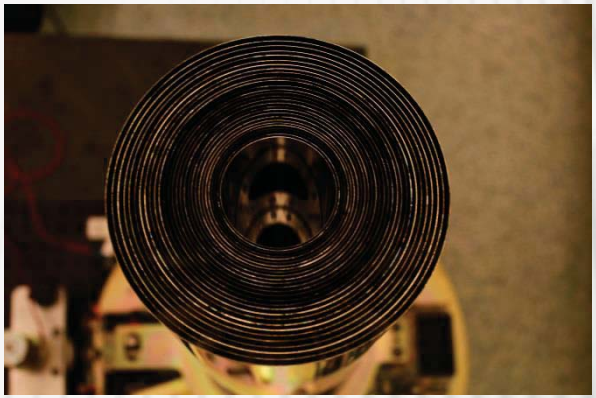
Detectors
Italy/INFN/INAF

Type	Gas pixel detector
Fill gas	He (20%) + DME (80%)
Pressure	1 atm
Detector sensitive area	18 x 18 mm
Modulation factor	~ 50% at 5 keV
Spatial Resolution	100 micron (4 keV)
Energy resolution	< 20 % at 6 keV
Energy range	2 – 8 keV

Heritage: X-ray Optics at MSFC

ART-XC (Satellite)



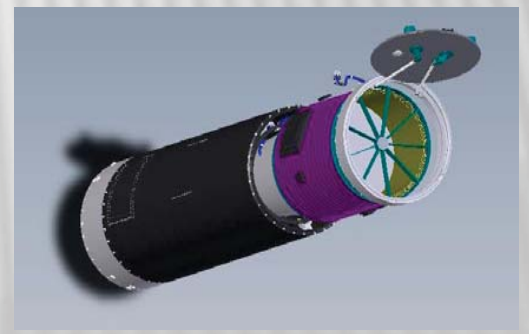


28-shell nested assembly

HEROES (Balloon)

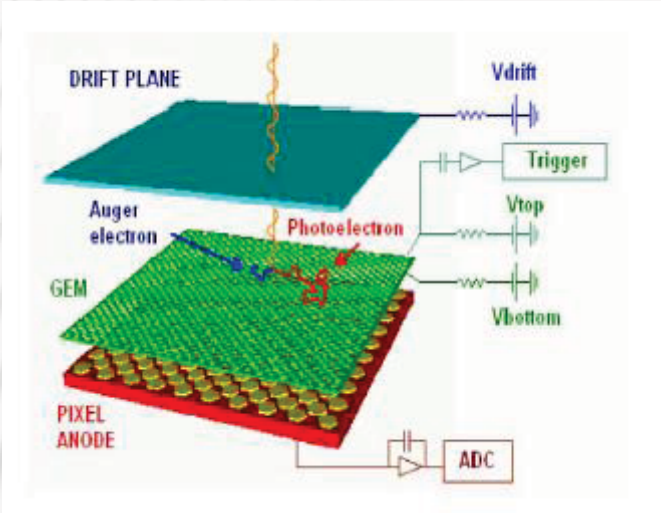
FOXSI (Rocket)

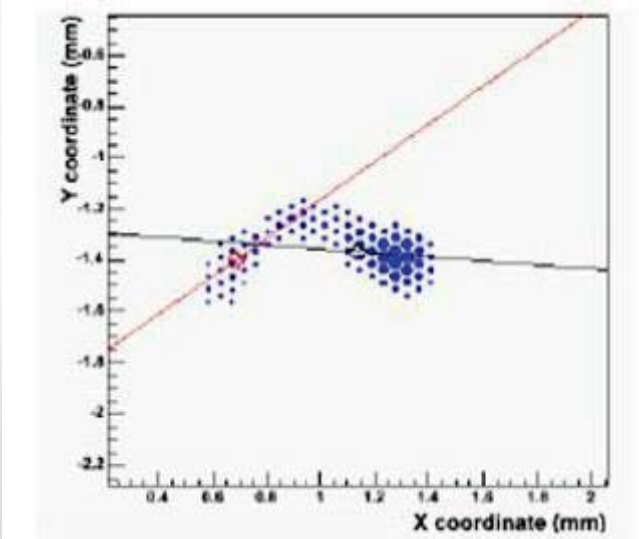
MicroX (Rocket)



Gas Pixel Detector

Principal of operation :





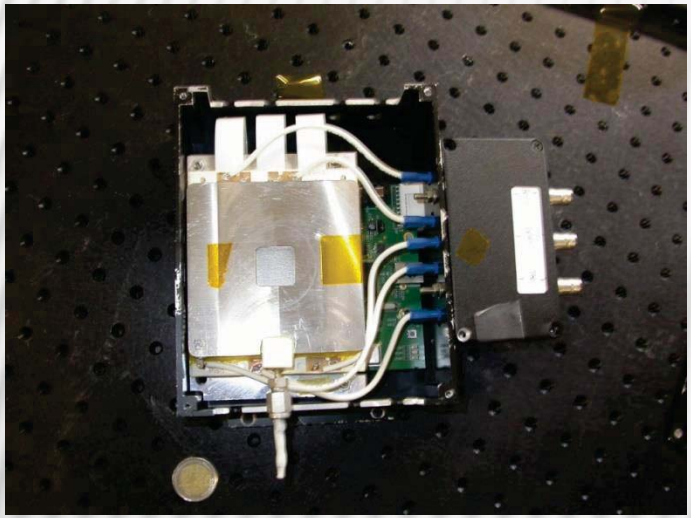
- Gas-filled imaging detector with GEM amplification stage
- Sensitive to single electrons
- Allows reconstruction of photoelectron tracks

- Typical photoelectron track image shown above
- Initial emission direction of photoelectron contains polarization information

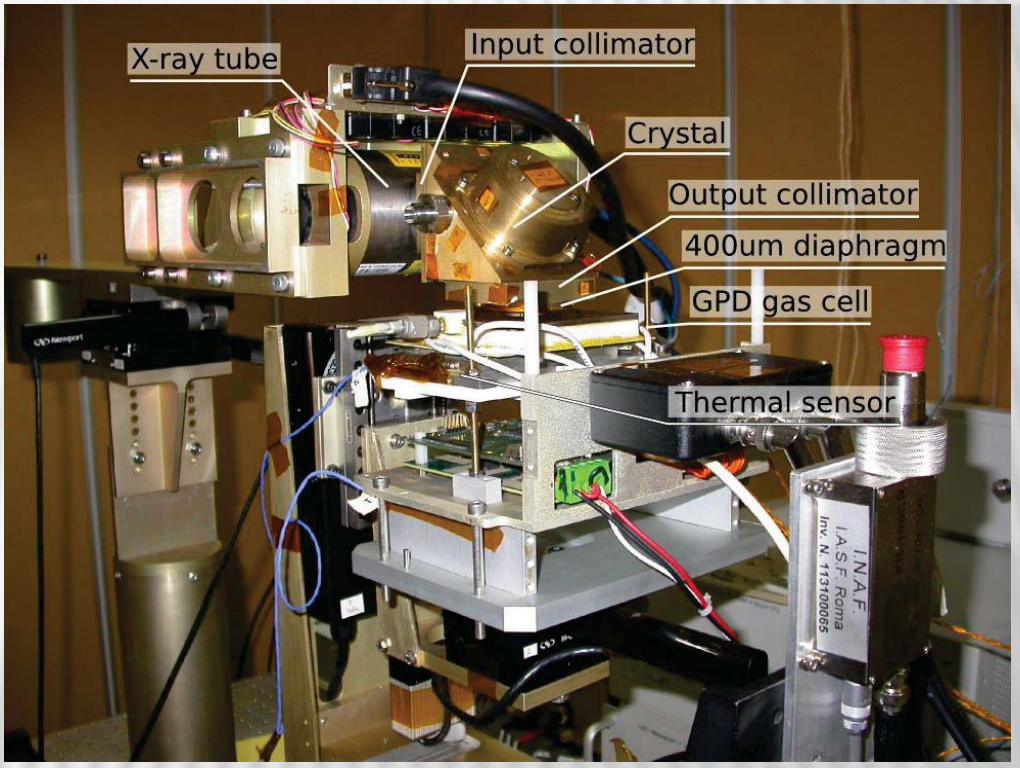
Heritage – Gas Pixel Detector

Under development in Italy (INAF + INFN) since early 2000's.

Latest iteration is well characterized and understood



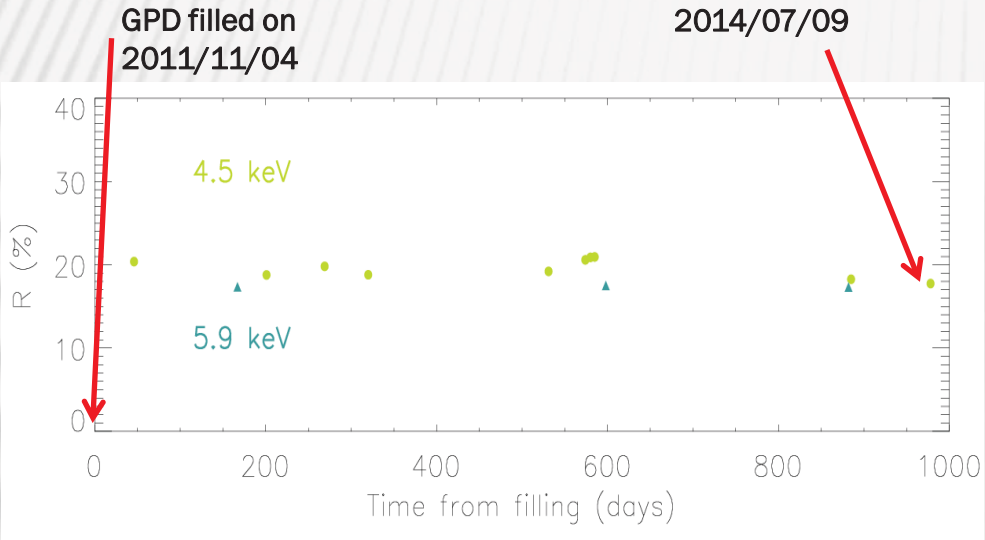
Gas Pixel detector



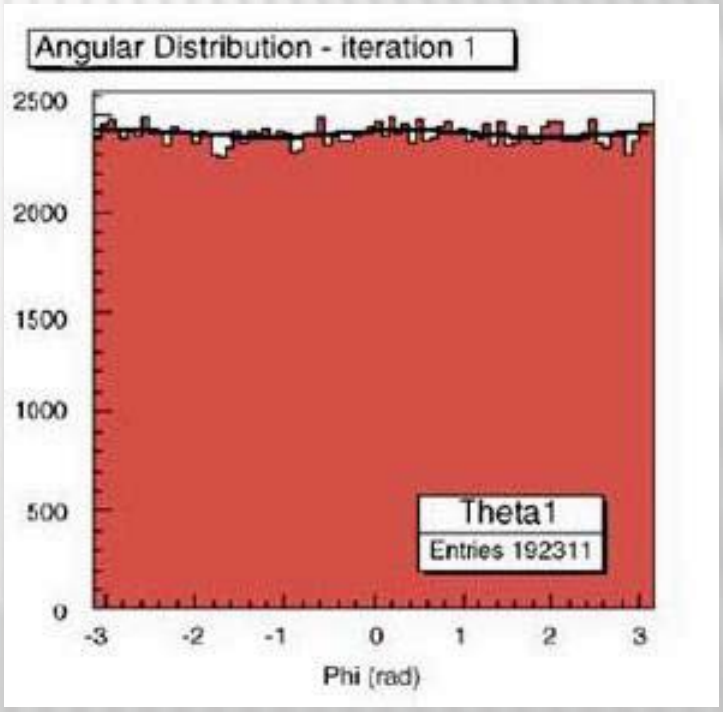
GPD being tested at INAF-IAPS

Heritage – Gas Pixel Detector

GPD - Long-term tests confirm stable operation over many years

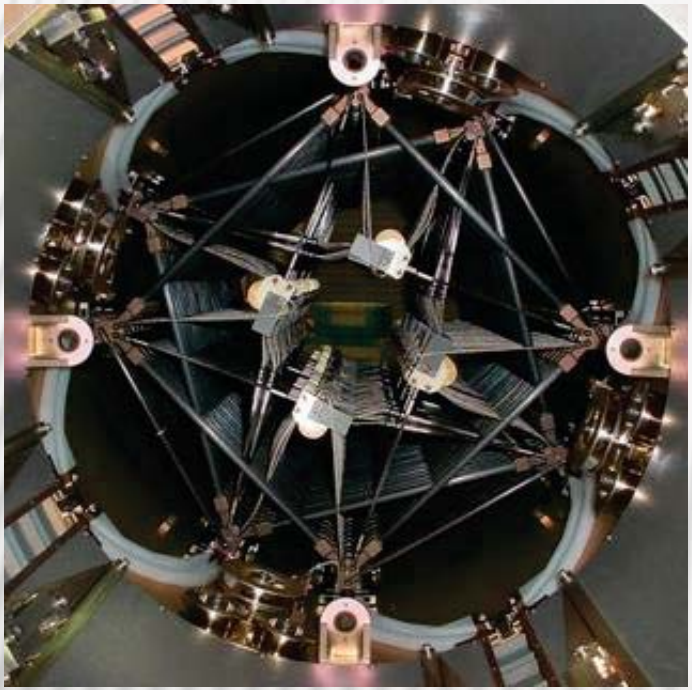


Any systematic effects are very low



Heritage: Extending Bench

Shorter version of NuSTAR boom/mast



NuSTAR boom/mast in stowed configuration

NuSTAR boom/mast deployed

Planned Full System Calibration

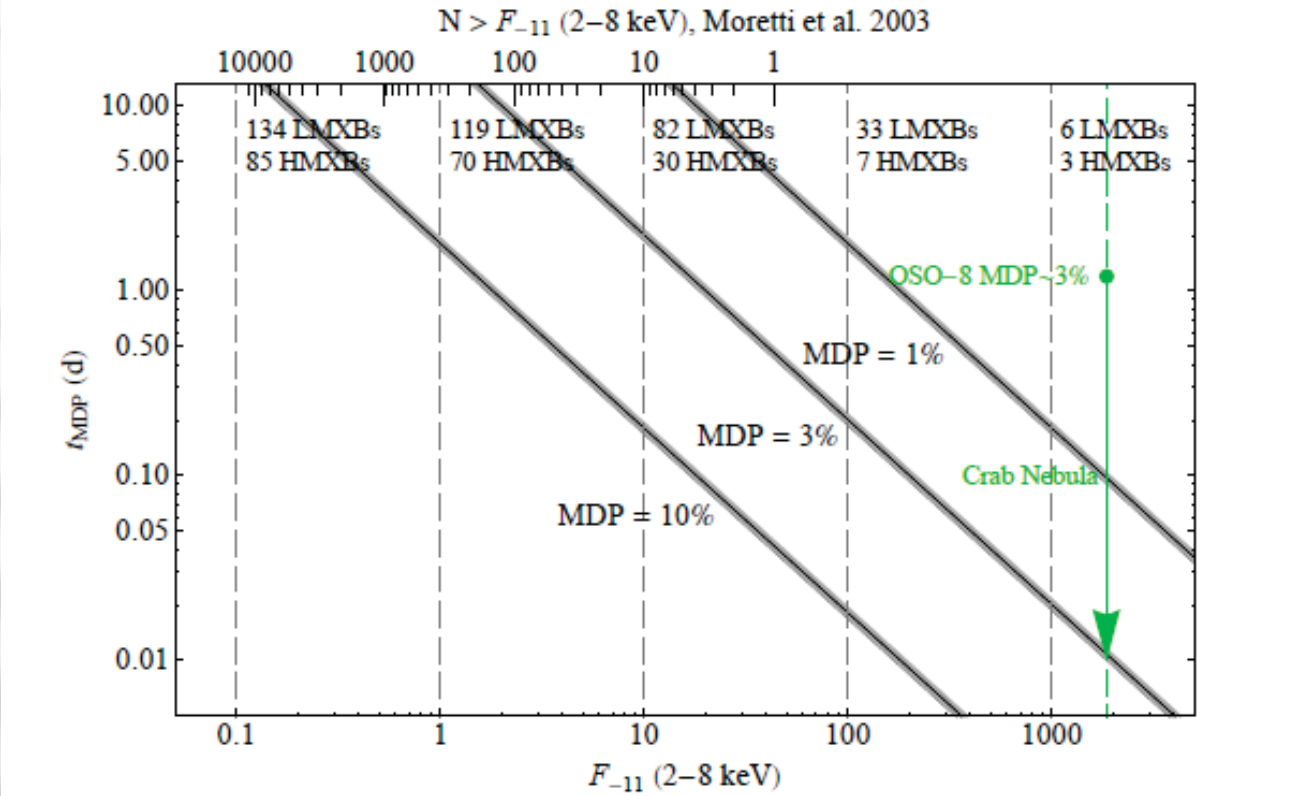


Precise calibration of IXPE is vital to ensuring sensitivity goals are met. The detectors will be characterized in Italy, and then a full calibration of the complete instrument will be performed at MSFC's stray light facility. Polarized flux at different energies will be obtained from the scattering crystals below

Energy (keV)	Line	Crystal/angle	Polarization
2.293	Molybdenum-Lα	Rhodium (001)/45.36°	0.9994
2.697	Rhodium-Lα	Germanium (111)/44.86°	0.9926
3.692	Calcium-Kα	Aluminum (111)/45.88°	0.9938
4.511	Titanium-Kα	Fluorite CaF2 (220)/45.37°	0.9994
5.899	Manganese-Kα	LithiumFluoride (220)/47.56°	0.8822
6.457	N/A (continuum)	Silicon (400)/45.00°	0.9999

IXPE Mission

IXPE will have unprecedented polarization sensitivity, 2 orders of magnitude more sensitive than original OSO-8 instrument



Time to obtain a specific Minimum Detectable Polarization (MDP)

IXPE Mission

Over the proposed mission life (2-3 years), IXPE will first survey representative samples of several categories of targets: magnetars, isolated pulsars, pulsar wind nebula and supernova remnants, microquasars, active galaxies etc. The survey results will guide detailed follow-up observations.

Typical plan shown

Name {"Bins"}	Type	T(d)	MDP(%)
Crab Nebula/Pulsar {8}	PWN & PSR	7.3	0.18/3.0
Vela	PWN	4.6	3.0
MSH15-52/B1509-58	PWN	1.0	10
G21.5-0.9 (J1833-1034)	PWN	0.464	3.0
4U 0142+61{10}	AXP	2.4	10.0
J1708-4009	AXP	3.6	10.0
SAXJ1808.4-3658 {4}	AMSP	4.0	3.0
XTE J1751-305 {4}	AMSP	2.8	3.0
AM Her	mCV Polar	2.41	5.0
V1223 Sgr	mCV Intermediate Polar	1.9	3
EX Hya	mCV Intermediate Polar	2	3
Sgr B2	Scattering from GC cloud	4.3	20
SS 433	μ-quasar	0.67	3
Her X-1 {30}	LMXB, Pulsing	2.1	5.0
GX 1+4 {30}	LMXB, Pulsing	1.4	5.0
1627-673 {12}	LMXB, Pulsing	2.3	5.0
Cen X-3 {12}	HMXB, Pulsing	5.8	5.0
2S 1553-542 {12}	HMXB, Pulsing	2.1	5.0
J16320-4751 {12}	HMXB, Pulsing	3.4	5.0
1915+105 {9}	LMXB, Transient, μ-quasar	0.32	1.0
J1655-40 {9}	LMXB, Dipper, μ-quasar	0.16	1.0
Sco X-1	LMXB, QPO, Z	0.045	1.0
GX 5-1	LMXB, QPO, Z	0.27	1.0
Cyg X-2	LMXB, QPO, Z	0.27	1.0
1636-536	LMXB, Bursts, Atoll	0.26	3.0
1728-337	LMXB, Bursts, Atoll	0.80	1.0
1820-303	LMXB, Bursts, Atoll	0.48	1.0
GS 1826-238	LMXB, Bursts, Transient	0.45	3.0
Cyg X-1 {9} low rate	HMXB, BH, radio, μ-quasar	0.51	1.0
Cyg X-3	HMXB, radio, μ-quasar	0.55	3.0
4U 1700-37	HMXB	1.2	3.0
Circinus Galaxy	Galaxy	2.3	10.0
Cen A {3}	AGN	2.4	4.0
MCG-5-23-16	AGN	3.0	3.0
MCG-6-30-15	AGN	3.9	3.0
IC 4329A	AGN	2.0	3.0
NGC 4151	AGN	1.8	3.0
3C 273 {3}	AGN	4.4	4.0
Mkn 421	Blazar	5.6	3.0
Mkn 501	Blazar	2.7	3.0
PKS 2155-304	Blazar	3.8	3.0
PKS 2005-489	Blazar	2.4	3.0
H1722+119	Blazar	1.9	3.0
1ES 1101-232	Blazar	3.4	3.0
1ES 0836+710	Blazar	1.9	5.0
S5 2116+81	Blazar	5.2	5.0

Schedule

Put tentative schedule here