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Microarticle

# The Imaging X-ray Polarimetry Explorer (*IXPE*)

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ABSTRACT

The Imaging X-ray Polarimetry Explorer (*IXPE*) expands observation space by simultaneously adding polarization to the array of X-ray source properties currently measured (energy, time, and location). *IXPE* will thus open new dimensions for understanding how X-ray emission is produced in astrophysical objects, especially in systems under extreme physical conditions.



## Introduction

*IXPE* brings together an international collaboration for flying an imaging X-ray polarimeter on a NASA Small Explorer. *IXPE* will conduct X-ray polarimetry for several categories of cosmic X-ray sources—from neutron stars and stellar-mass black holes, to supernova remnants, to active galactic nuclei—that are likely to be X-ray polarized. For the brighter extended sources—Pulsar Wind Nebulae (PWNe), Supernova Remnants (SNR), and a large-scale jet in an Active Galactic Nucleus (AGN)—*IXPE* will perform X-ray polarimetric imaging.

## The approach

*IXPE* is comprised of three X-ray telescopes with identical mirror modules and identical polarization-sensitive imaging detectors at their foci. The mirror modules are based upon nickel–cobalt replicated optics developed by Marshall Space Flight Center (MSFC). MSFC recently delivered 8 fully flight-qualified mirror modules to Russia as part of another (*ART-XC*) flight program. The X-ray detectors, invented and developed by the *IXPE* Italian partners, are especially well suited for polarimetry and a prototype has undergone full qualification—including lifetime testing. Based upon proportional counters with highly-pixelated readouts, these detectors offer low gain (not susceptible to sparking) and two-dimensional symmetry (nearly unsusceptible to systematic effects).

The basic scientific operating parameters are as follows:

- 2–8 keV energy range
- Proportional counter energy resolution
- <100 μs time resolution
- >11′ field of view (FOV)
- ⩽30″ half-energy width (HEW) angular resolution

Fig. 1 shows a mechanical drawing of *IXPE* as seen along the optical axis from left to right. The spacecraft (S/C) and its solar panels are on the left and the rear of the three telescopes assemblies are on the right. The overall length from aft of the S/C to the front of the optics is approximately 5 m. At the heart of each telescope system is a polarization-sensitive imaging detector (Fig. 2) that allows broadband X-ray polarimetry with low net background and minimal, if any, systematic effects. Invented and developed by Italian members of the team [1] and refined over the past

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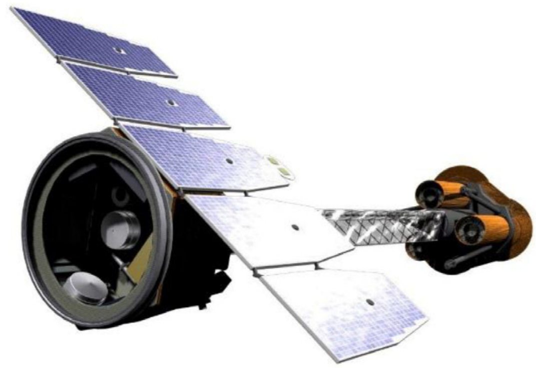

**Fig. 1.** Mechanical drawing of IXPE on-orbit.

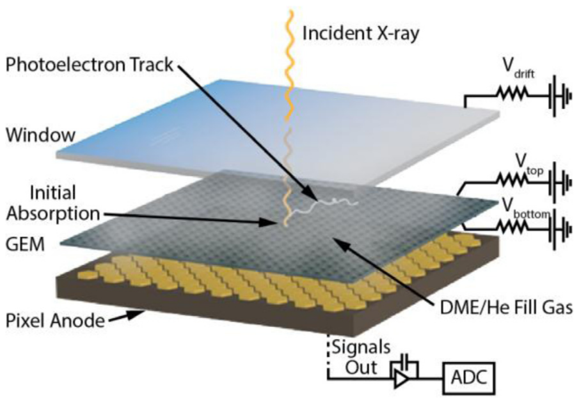


**Fig. 2.** Schematic of the polarization-sensitive gas pixel detector.

15 years to a high level of maturity, these Gas Pixel Detectors (GPD) utilize the anisotropy of the emission direction of photoelectrons produced by polarized photons to gauge with high sensitivity the polarization state of X-rays interacting in a gaseous medium. In photoelectric interactions—the dominant interaction process for 2–8 keV photons—the ejected K-shell photoelectron has an emission direction peaked around that of the electric field of the photon with a $\cos^2$ distribution. Thus, for polarized X-rays, photoelectrons are preferentially emitted in the polarization direction. After ejection, each photoelectron interacts with the surrounding gas and is slowed by ionizing collisions and scattered by nuclei until it eventually stops. The resulting string of ionization, or photoelectron "track", marks the path of the photoelectron from its creation at the original X-ray interaction site to its stopping point. It is in the initial part of this track where the information on the original electron direction is recorded. The distribution of these directions for many detected tracks then determines both the degree of polarization and the position angle associated with the incident photon beam.

## Discussion – benefits of imaging

With its imaging capabilities, *IXPE* can obtain scientifically meaningful polarimetric images of the brightest extended X-ray sources—an Active Galactic Nucleus (AGN) jet, a few Pulsar Wind Nebulae (PWNe), and a few (shell-type) Supernova Remnants (SNR). Position- and energy-dependent polarization maps of such synchrotron emitting sources will elucidate the magnetic-field structure of the X-ray emitting regions, which may differ from those of regions emitting in other spectral bands (radio or visible, where available). As radiative lifetimes for X-ray-emitting electrons are much shorter than those of electrons radiating at lower energies, X-ray polarimetric imaging better indicates the magnetic structure in regions of strong electron acceleration.

Besides mapping the X-ray polarization of extended sources, *IXPE* imaging capabilities avoid source confusion in several cases by resolving point sources from surrounding nebular emission or from adjacent point sources. In the absence of good angular resolution, polarization measurements of individual sources in a confused region are impossible without other information—e.g., phase-resolved flux of a pulsed source. Even in those cases where a pulsed point source can be isolated from a steady extended source using phase-resolved data, the statistical noise due to the extended source the sensitivity depends upon the angular resolution of the telescope system.

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