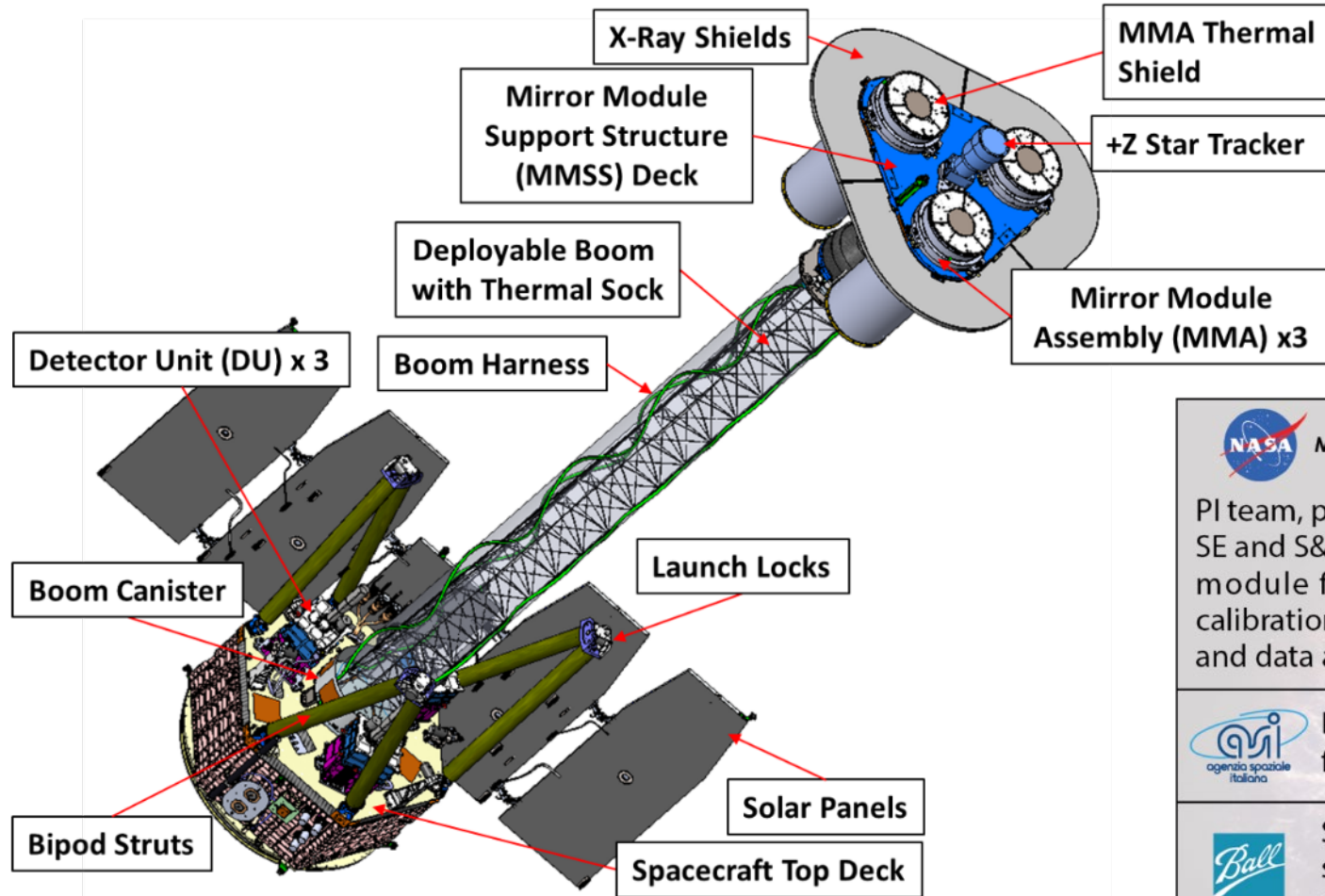


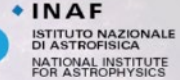








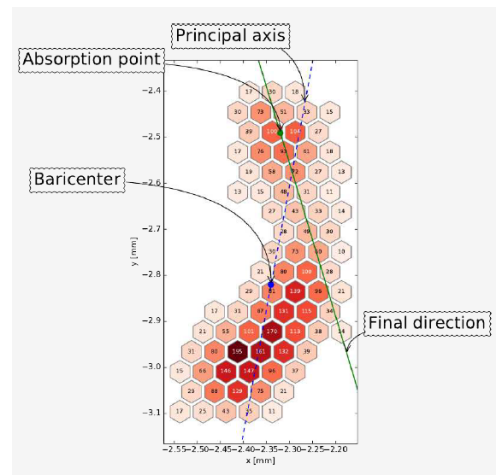
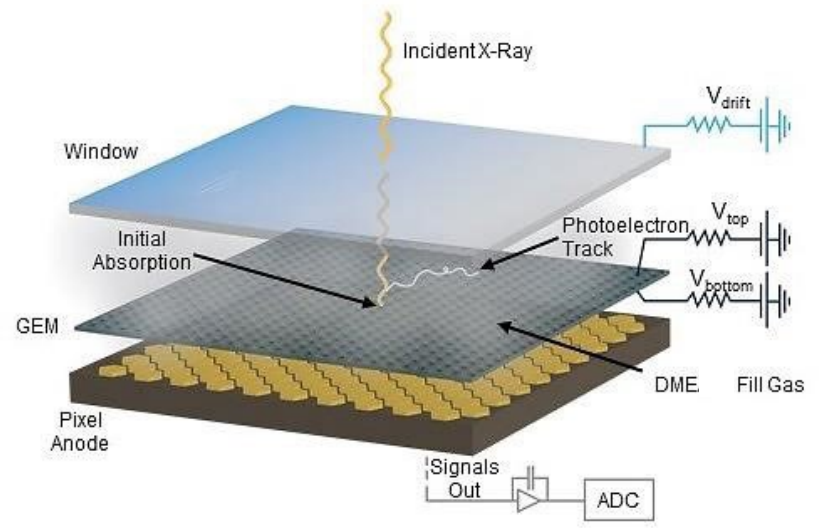


The Imaging X-ray Polarimetry Explorer (IXPE) Mission

Brian Ramsey, IXPE Deputy Principal Investigator
NASA Marshall Space Flight Center
For the IXPE Team



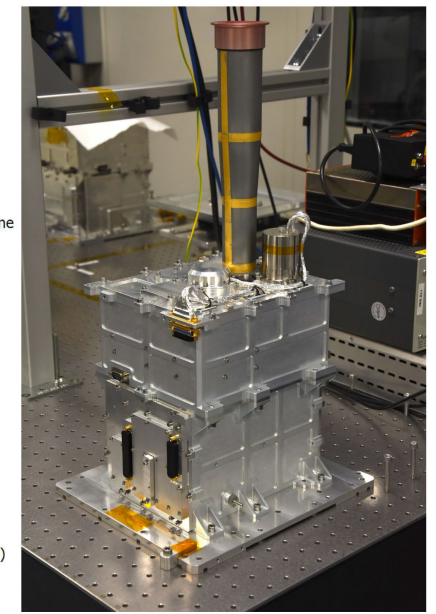
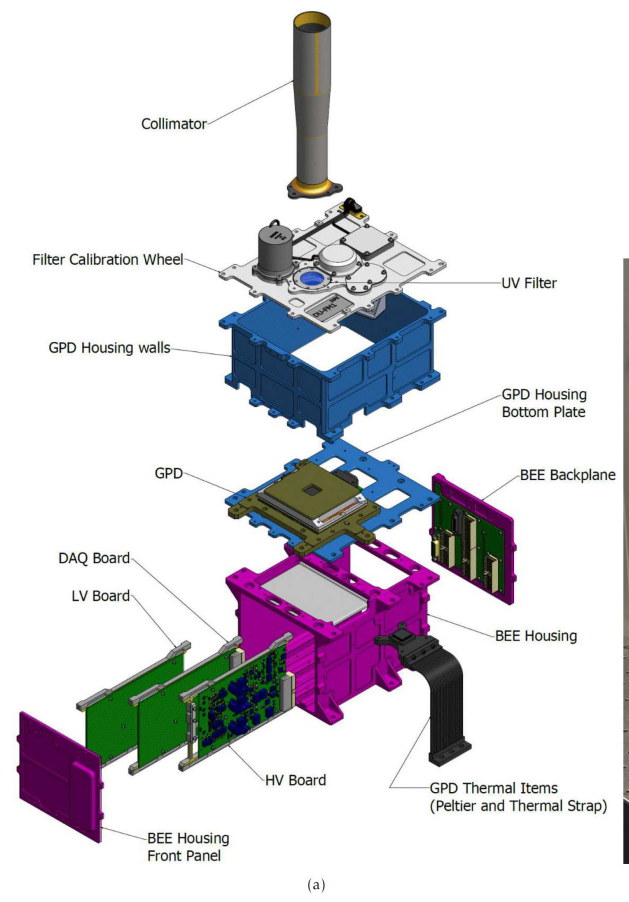
 Marshall Space Flight Center PI team, project management, SE and S&MA oversight, mirror module fabrication, X-ray calibration, science operations, and data analysis and archiving	     Polarization-sensitive imaging detector systems
 ASI agenzia spaziale italiana Detector system funding, ground station	 LASP Mission operations   Stanford University Scientific theory  Nagoya University Thermal Shields  MIT Massachusetts Institute of Technology Co-Investigator



Photoelectron track analysis

The gas pixel detector, the heart of the detector unit, tracks photoelectrons to reconstruct the initial ejection direction, which correlates to the polarization position angle of absorbed photon

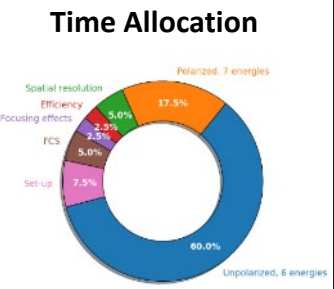
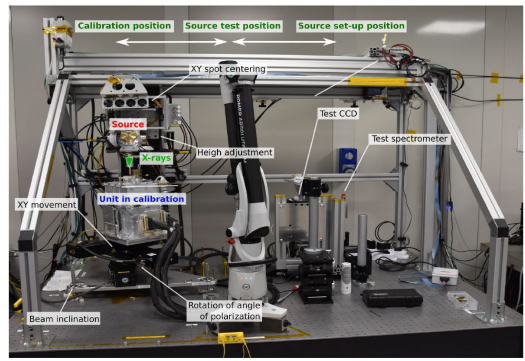
Parameter	Value
Sensitive area	15 mm × 15 mm (13 x 13 arcmin)
Fill gas and asymptotic pressure	DME @ 0.656 atmosphere
Detector window	50- μ m thick beryllium
Absorption and drift region depth	10 mm
Spatial resolution (FWHM)	$\leq 123 \mu\text{m}$ (6.4 arcsec) @ 2 keV
Energy resolution (FWHM)	0.57 keV @ 2 keV ($\propto \sqrt{E}$)
Useful energy range	2 - 8 keV



Expanded view of a detector unit (left) and a completed flight detector unit (right)

Detector Calibration in Italy (July 2019 – Sep 2020)

Instrument Calibration Equipment (ICE)

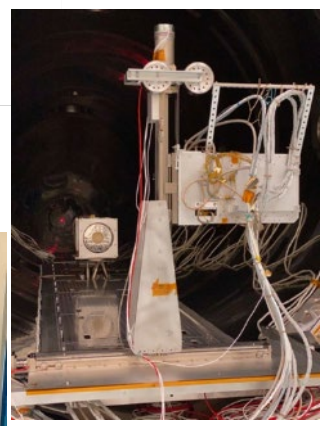
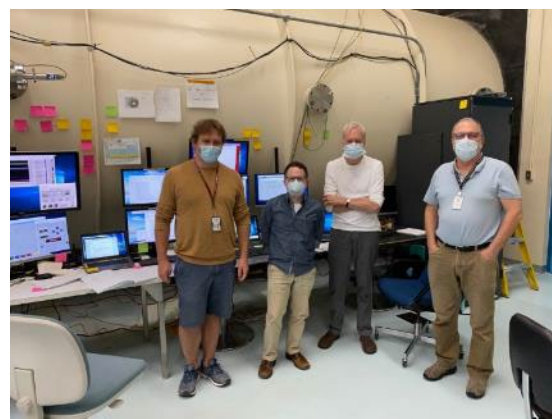
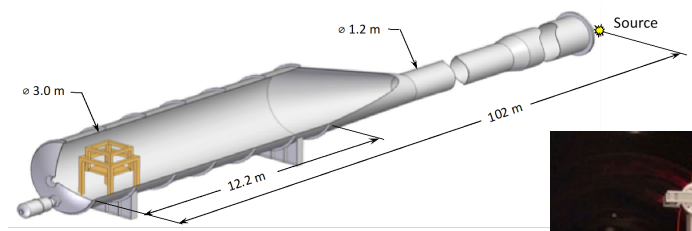


Polarized Sources Used

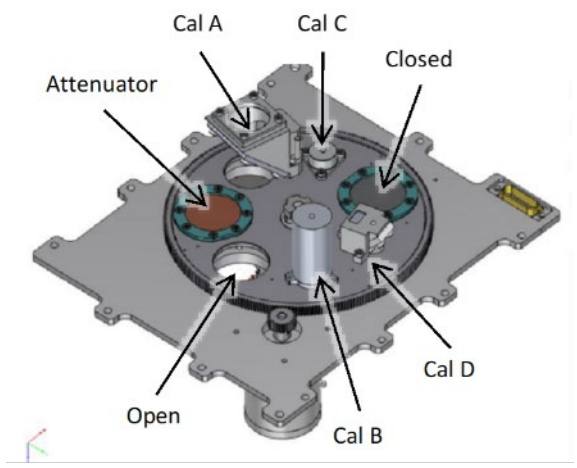
Crystal	X-ray Tube	Energy (keV)	Diffraction Angle	Polarization (%)
PET (002)	Continuum	2.01	45.0	~ 100
InSb (111)	Mo L	2.29	46.4	99.2
Ge (111)	Rh L	2.70	44.9	~ 100
Si (111)	Ag L	2.98	41.6	95.1
Al (111)	Ca K	3.69	45.9	99.4
Si (220)	Ti K	4.51	45.7	99.5
Si (400)	Fe K	6.40	45.5	~ 100

MMA and Telescope Calibration at MSFC (July 2020 – Jan 2021)

MSFC Stray Light Test Facility



On-Board Calibration



Filter and Calibration Wheel (FCW) , with four ⁵⁵Fe-powered calibration sources:

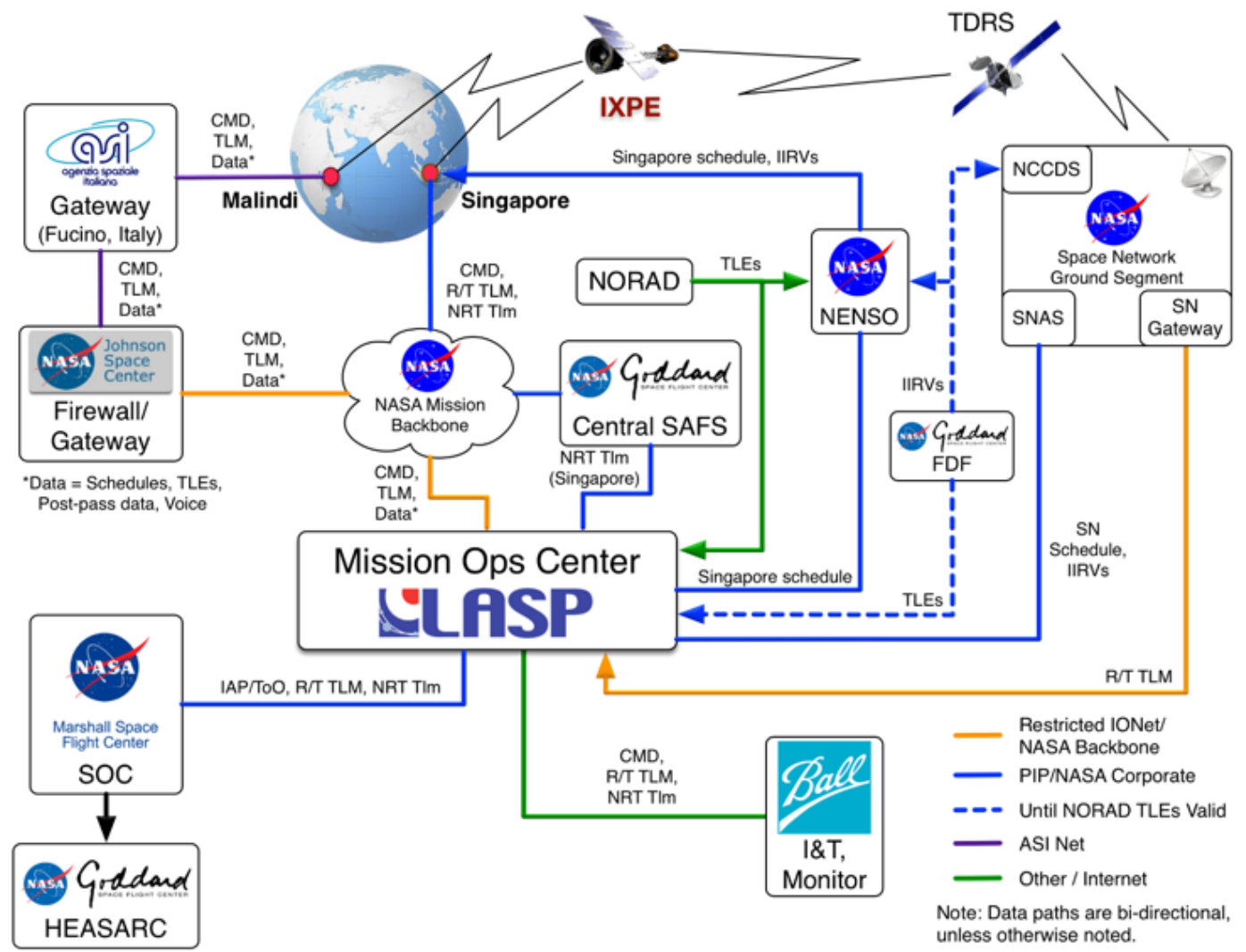
- Cal A – Bragg-reflected polarized 2.98-keV (Ag-L α fluorescence) and 5.89-keV (Mn-K α)
- Cal B – unpolarized 5.89-keV spot
- Cal C – unpolarized 5.89-keV flood
- Cal D – unpolarized 1.74-keV (Si-K α fluorescence) flood

Launch date	December 9, 2021 at 1 am (EST)
Launch vehicle	Falcon 9
Orbit altitude	~ 600 km
Orbit inclination	~ 0 deg
Baseline mission	2 years
General observer program	Year 3 and beyond
Orbit lifetime	18 years, no consumables on board
Energy band	2-8 keV
Polarization sensitivity (MDP)	5.5% for 10^{-11} ergs / cm^2 s (10-day exposure time)
Field of view	10 arcmin (3 telescopes)
Angular resolution	28 arcsec HPD
Energy Resolution	19% FWHM at 4.5 keV
Timing accuracy	20 μs

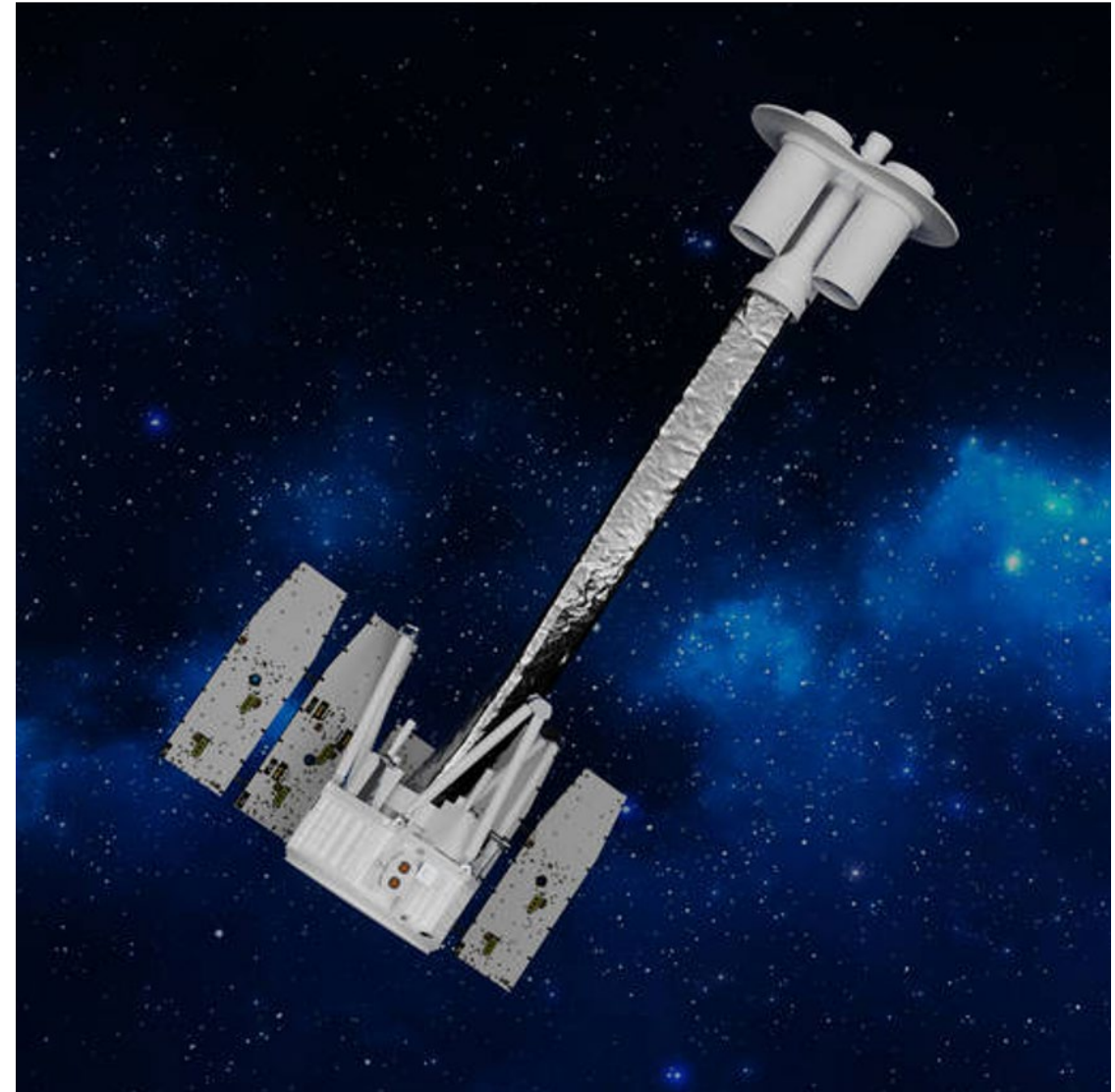


IXPE launch from Cape Canaveral

- Malindi ground station - primary (Singapore - secondary)
 - Typically use ~ 7 contacts / day
- Mission Operations Center (MOC) at the University of Colorado, Laboratory for Atmospheric and Space Physics (LASP)
- Sciences Operations Center (SOC) at NASA's MSFC
- Data archiving at NASA's HEASARC
 - Every effort made to get data to the HEASARC within 1 week of the end of an observation, which is defined as when data for 90% of the scheduled observation time are received by the MOC.
- <https://heasarc.gsfc.nasa.gov/docs/ixpe/>
- Data products
 - Level-1: time, track information, electron ejection angle, detector location, sky position, all data including calibration and occultation
 - Level-2: time, energy, moment, Q, U, sky position, only target data, bad pixel and outer border removed

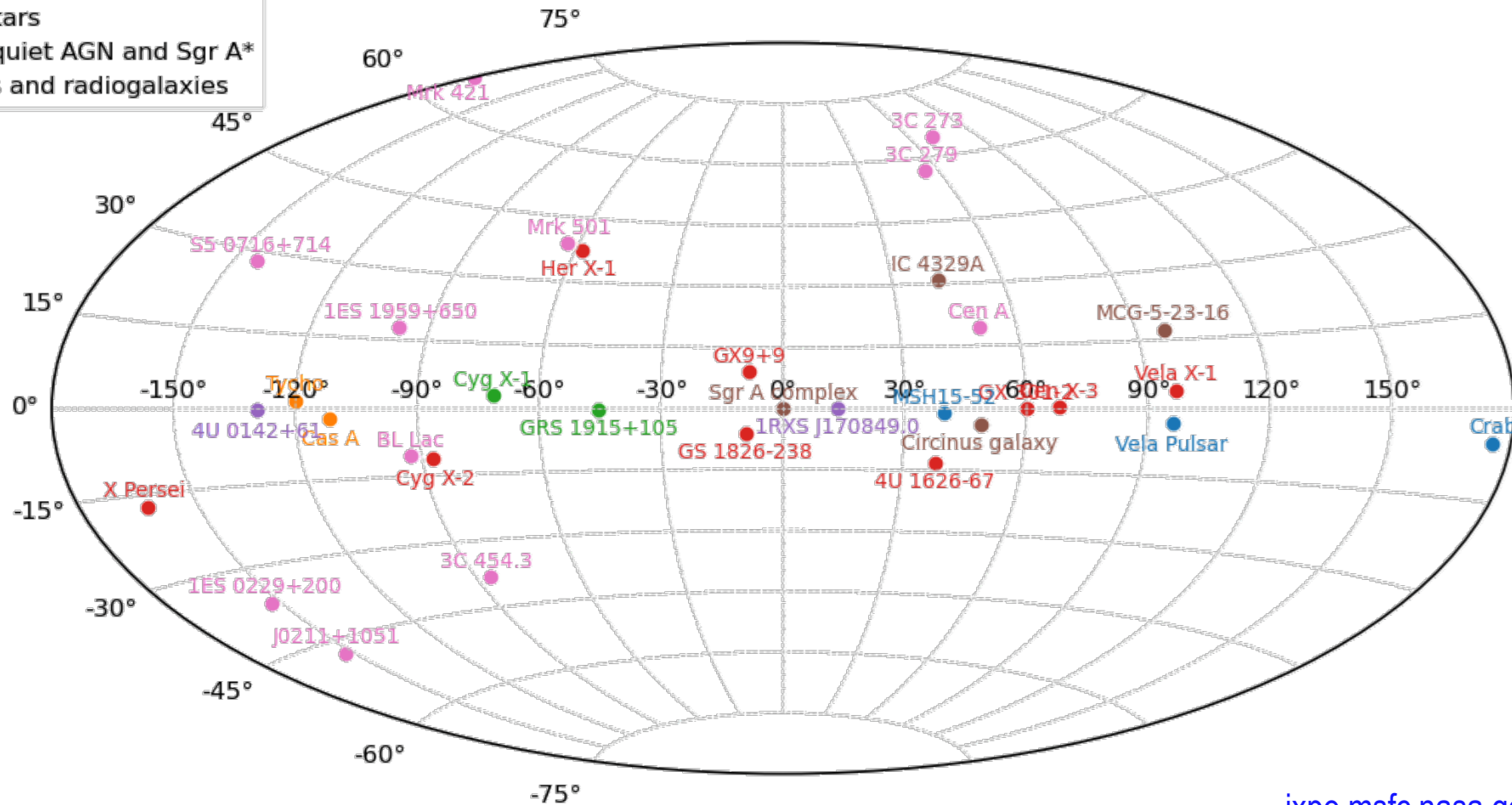


- **Science Working Group**
 - Serves as steering group comprised of official mission investigators (Principal and Co- Investigators)
- **Science Analysis and Simulation Working Group**
 - Coordinates development of software for advanced analysis and simulation of IXPE observations
 - Including `ixpeobssim`
 - Chaired by Luca Baldini (INFN-Pisa) and Herman Marshall (MIT)
- **Science Advisory Team**
 - Coordinates science activities required for planning, analyzing, interpreting, and reporting IXPE observations
 - Chaired by Giorgio Matt (Uni Roma Tre) and Roger Romani (Stanford)
 - Organized into seven Topical Working Groups
 - TWG1 Pulsar Wind Nebulae, led by Niccolò Bucciantini (INAF-Arcetri)
 - TWG2 Supernova Remnants, led by Pat Slane (CfA)
 - TWG3 Accreting Black Holes, led by Michal Dovčiak (CAS-ASU)
 - TWG4 Accreting Neutron Stars, led by Juri Poutanen (Turku)
 - TWG5 Magnetars, led by Roberto Turolla (Uni Padua)
 - TWG6 Radio-Quiet AGN & Sgr A, led by Frédéric Marin (Strasbourg)
 - TWG7 Blazars & Radio Galaxies, lead by Alan Marscher (Boston U)
 - Recommends list of targets for observation during the baseline (2-year) mission
 - For an extended mission, HEASARC will administer an IXPE General Observer (GO) program



Galactic Coordinates

- PWN and radio pulsars
- SNR
- Accreting stellar-mass BH
- Accreting WD and NS
- Magnetars
- Radio-quiet AGN and Sgr A*
- Blazars and radiogalaxies



- IXPE has been performing extremely well over its 6 months in orbit thus far
- The year-1 plan contains approx. 33 targets (plus time set aside for targets of opportunity)
- To date, 23 separate targets have been observed
- 8 of these have statistically-significant levels of polarization measured
 - 6 of these are presented in this session.
- After 50 years (first X-ray polarization measurement of Crab Nebula), sensitive imaging polarimetry has arrived (100 sigma for IXPE Crab measurement)!



IXPE solar panels deploying after release from Falcon-9 fairing