IXPE
Imaging
X-Ray
Polarimetry
Explorer

The Imaging X-ray Polarimetry Explorer

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NASA/Marshall Space Flight Center

Presentation to the APAC

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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

Detector system funding, ground station

Spacecraft, payload structure, payload, observatory I&T

Polarization-sensitive imaging detector systems

Mission operations

Scientific theory

Co-Investigator

Co-Investigator

Science Advisory Team

SAT currently comprises > 80 scientists from 12 countries

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Mission Description

- Launch Spring 2021 on a Falcon 9 from KSC
- > 540-km circular orbit at a nominal 0° inclination
- 2-year baseline mission, optional extension with GO program
- Point and stare (with dither) at pre-selected targets
- Malindi ground station - primary (Singapore - secondary)
- Mission Operations Center at the University of Colorado, Laboratory for Atmospheric and Space Physics (LASP)
- Sciences Operations Center at MSFC
- Data archiving at NASA's HEASARC
  - During the first 3 months of the mission, including one month of orbital checkout, all IXPE data shall be made publicly available at the HEASARC within 30 days of the end of an observation, which is defined as when data for 90% of the scheduled observation time are received by the MOC.
  - After the first 3 months of the mission, data shall be made available 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.

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MILESTONES

- Passed Mission Critical Design Review – 6/2019
- Ground System CDR – 11/2019
- Delivery of one flight Detector Unit (DU) to MSFC – 12/2019
  - For end-to-end calibration with a flight mirror module assembly (MMA)
- Delivery of two DUs and their computer (DSU) – 3/2020
- Delivery of MMAs + third Detector Unit to Ball – 4/2020
- Systems Integration Review (SIR) – Spring/2020
- Start of payload integration at Ball – 2/2020
  - Involves more than just the DUs, DSU, and MMAs
- Start of S/C Integration at Ball – 2/2020
- Launch – Spring/2021

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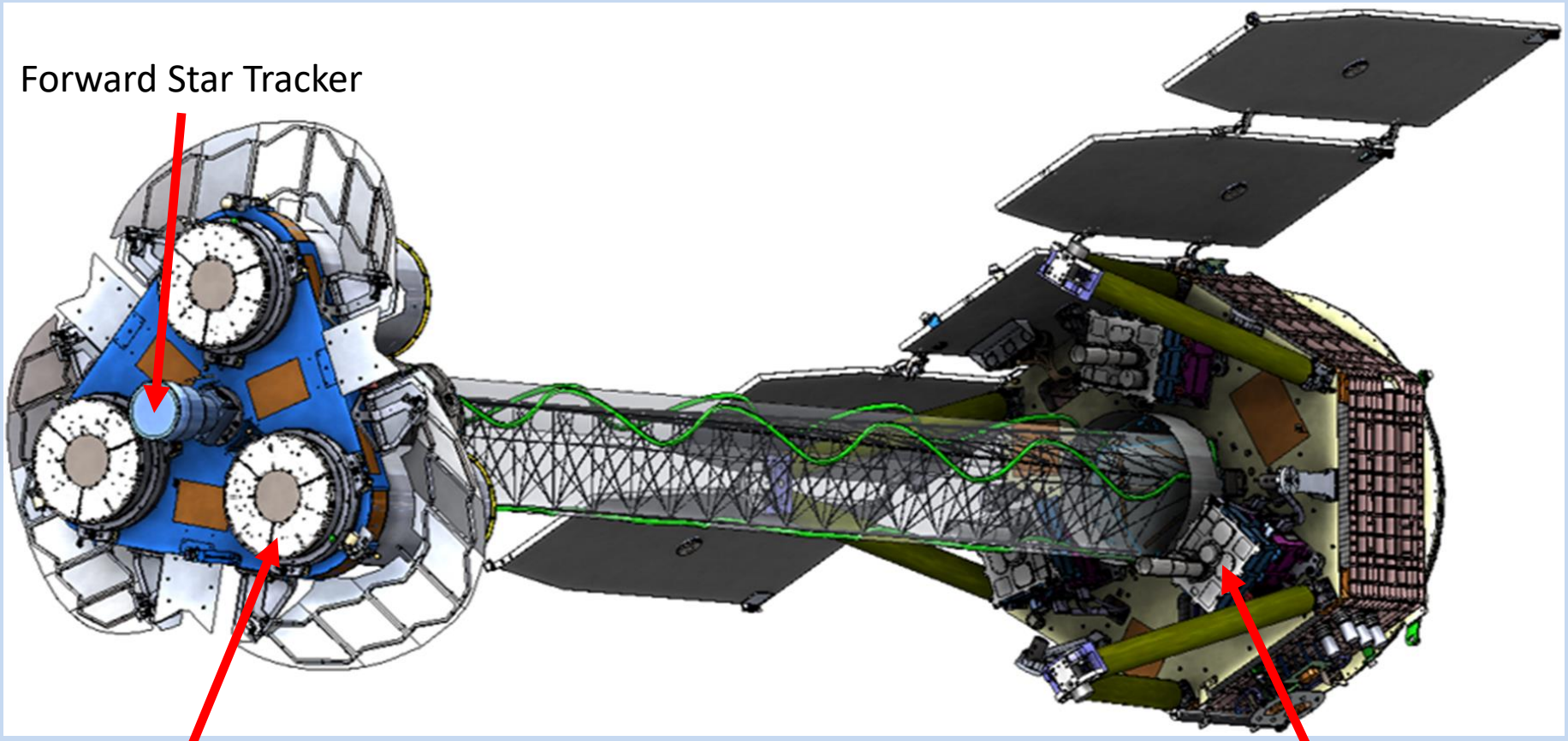
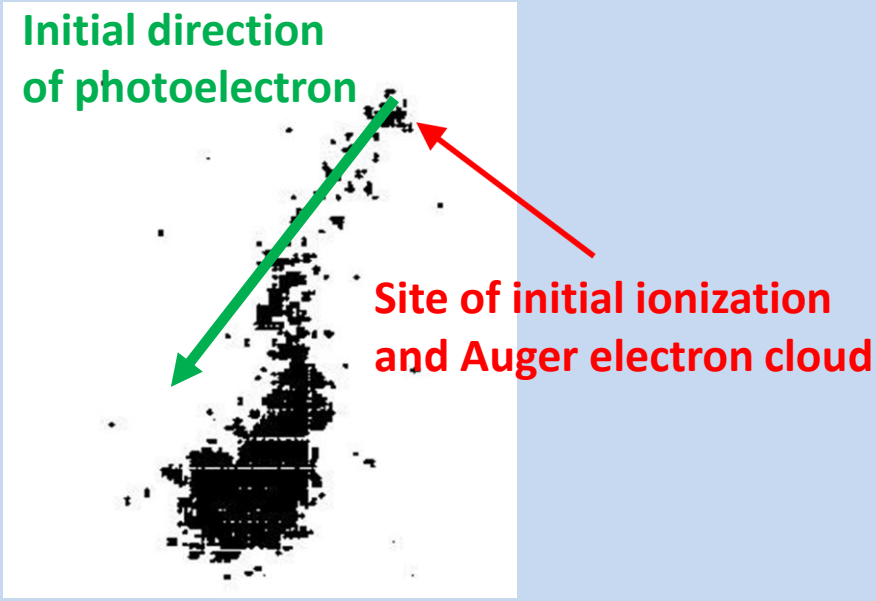
IXPE Deployed

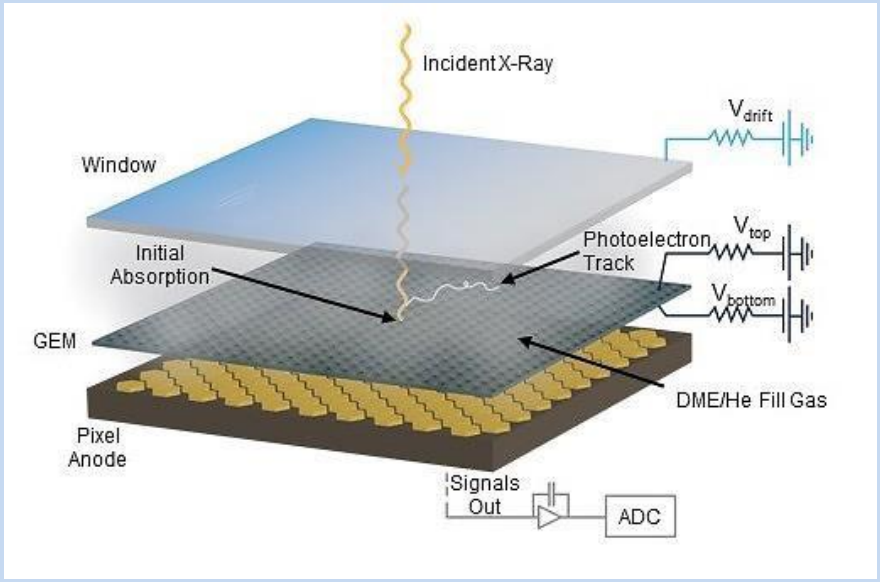


5.2 m total length
4.0 m focal length

THE POLARIZATION-SENSITIVE DETECTORS

- **The initial direction of the K-shell photoelectron is determined by the electric vector**





The distribution of the photoelectron initial directions determines the degree of polarization and the position angle

$$\frac{d\sigma}{d\Omega} = f(\zeta) r_0^2 Z^5 \alpha_0^4 \left(\frac{1}{\beta}\right)^{7/2} 4\sqrt{2}\sin^2\theta\cos^2\varphi\,, \text{ where } \beta \equiv \frac{E}{mc^2} = \frac{h\nu}{mc^2}$$

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Detector Properties

Parameter	Value
Sensitive area	15 mm × 15 mm (13 x 13 arcmin)
Fill gas and composition	DME @ 0.8 atmosphere
Detector window	50-µm thick beryllium
Absorption and drift region depth	10 mm
GEM (gas electron multiplier)	copper-plated 50-µm liquid-crystal polymer
GEM hole pitch	50 µm triangular lattice
Number ASIC readout pixels	300 × 352
ASIC pixelated anode	Hexagonal @ 50-µm pitch
Spatial resolution (FWHM)	≤ 123 µm (6.4 arcsec) @ 2 keV
Energy resolution (FWHM)	0.54 keV @ 2 keV ($\propto \sqrt{E}$)
Useful energy range	2 - 8 keV

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MIRROR MODULE ASSEMBLY – ENGINEERING UNIT

Inner shells (3)

Mass Simulators

Front Spider

Thermal Shields

Outer Housing

Measured angular resolution 20 arcsec @ 2.3 and 4.5 keV

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FLIGHT MIRROR MODULE ASSEMBLIES

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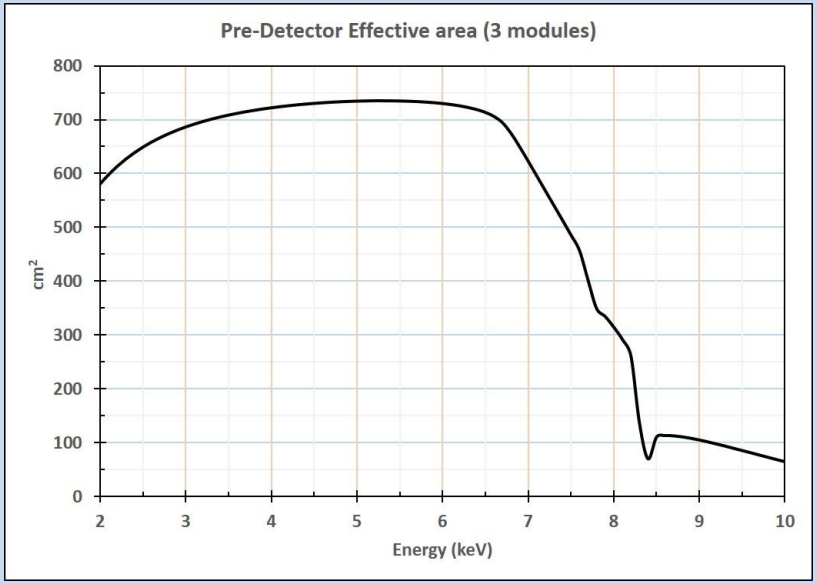
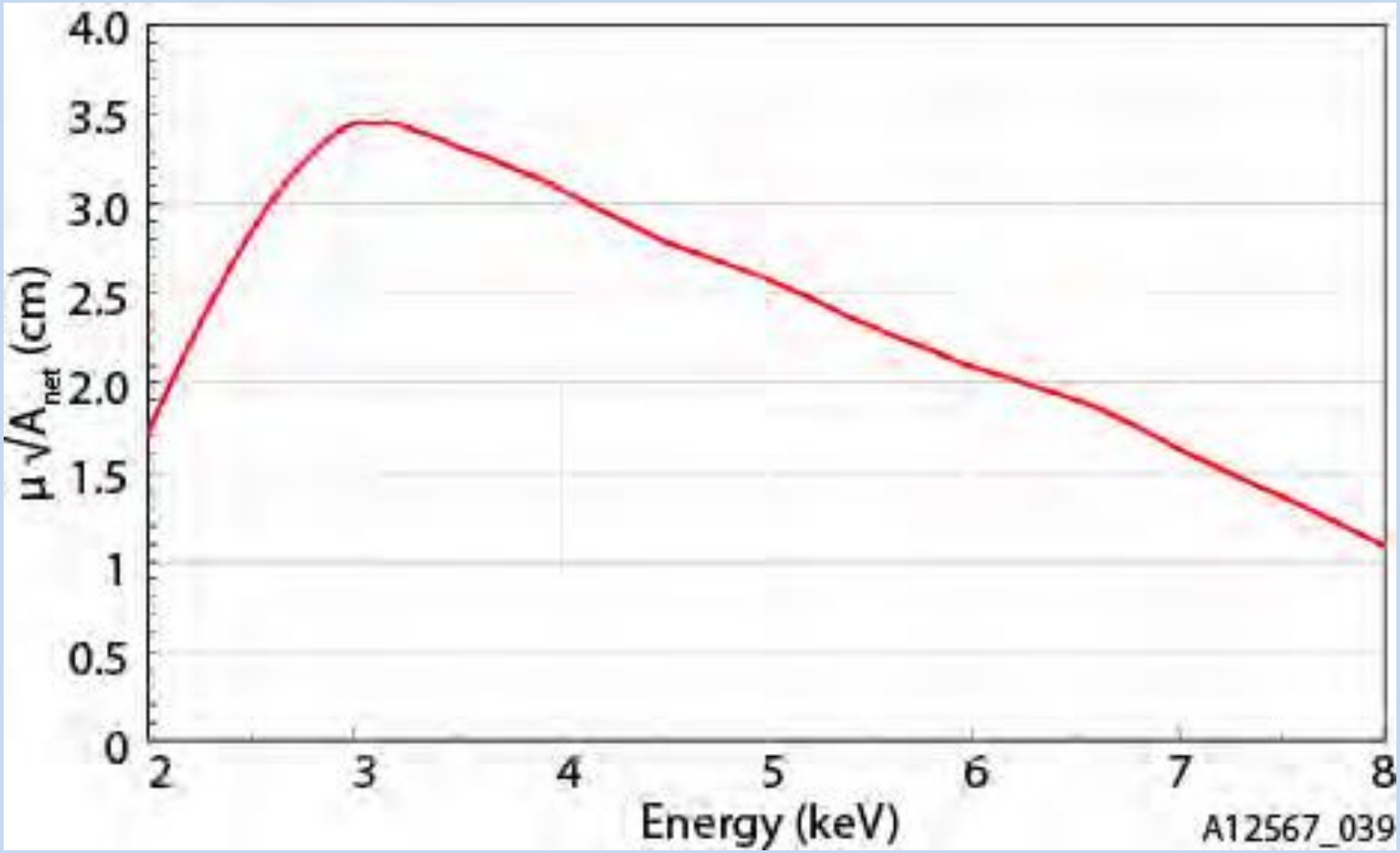
Mirror Module Assembly

Property	Value
Number of modules	3
Mirror shells per module	24
Inner, outer shell diameter	162, 272 mm
Total shell length	600 mm
Inner, outer shell thickness	180, 260 µm
Shell material	Nickel cobalt alloy
Effective area per module	210 cm^2 (2.3 keV) > 230 cm^2 (3-6 keV)
Angular resolution	≤ 25 arcsec HPD
Detector limited FOV	12.9 arcmin
Focal length	4 m
Mass (3 assemblies)	95 kg with contingency



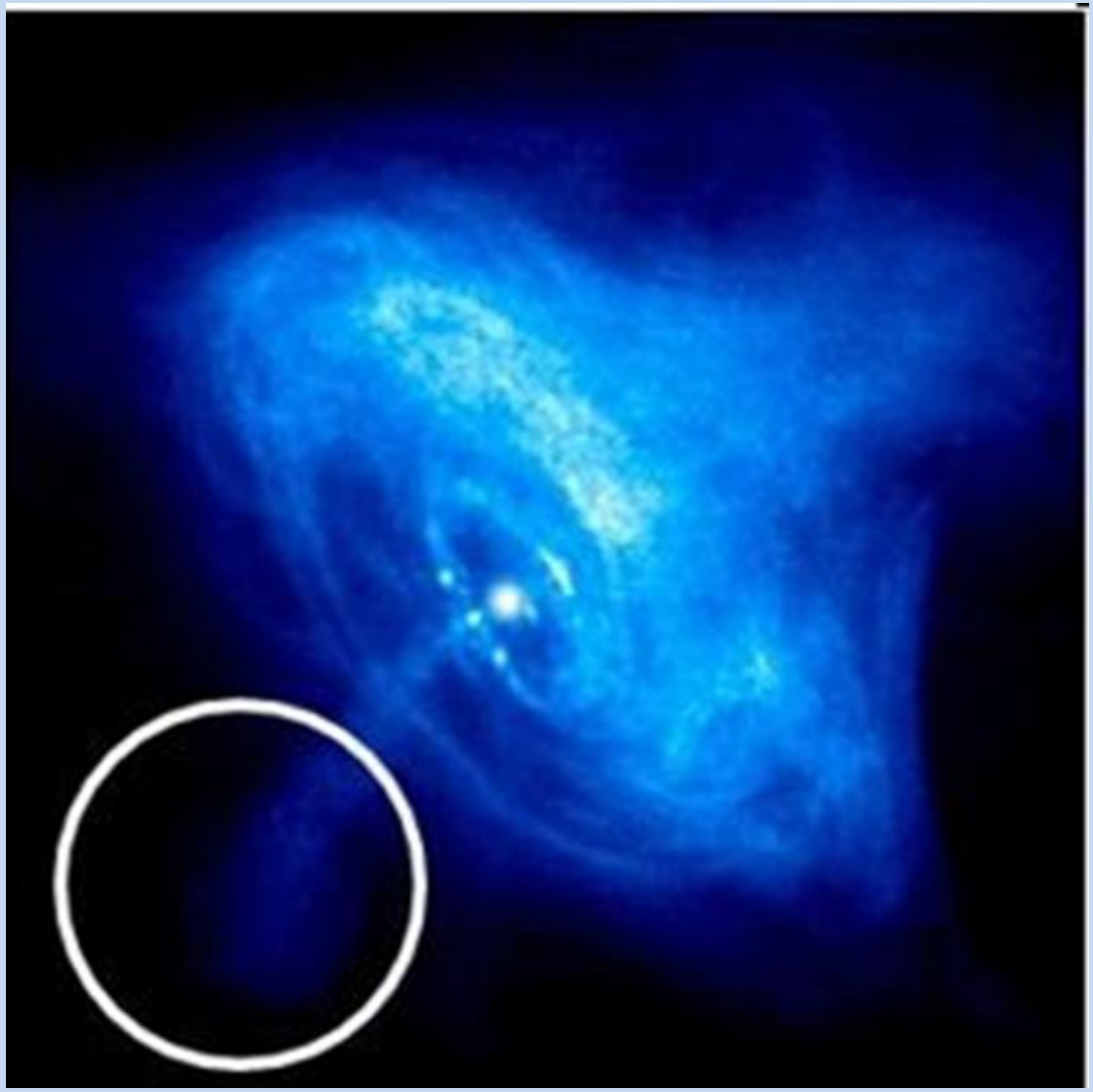
POLARIZATION SENSITIVITY FIGURE OF MERIT



- μ is the "modulation factor" i.e. the modulation of the distribution of position angles for a 100%-polarized beam
- A_{net} is the net effective area (mirrors plus detectors)

IMAGING POLARIMETRY

- **IXPE 30” half-power diameter on Chandra image**



RADIO PULSARS

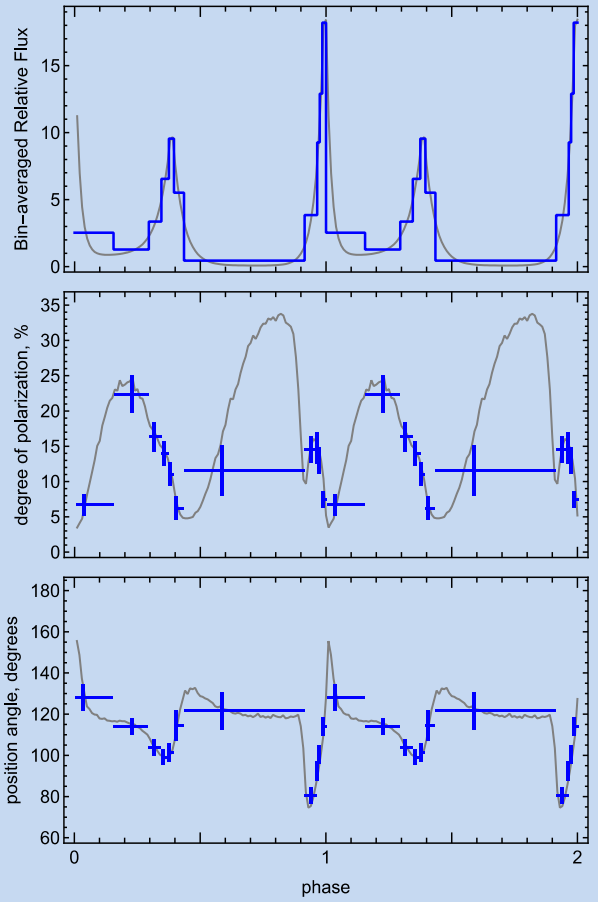
- **Radio Pulsars**
  - **Perform X-ray phase-resolved polarimetry to test models for a radio pulsar's X-ray emission**
  - **Grey is optical, blue is IXPE**

Emission geometry and processes are still unsettled.

- **Competing models predict differing polarization behavior with pulse phase.**

X-rays provide clean probe of geometry.

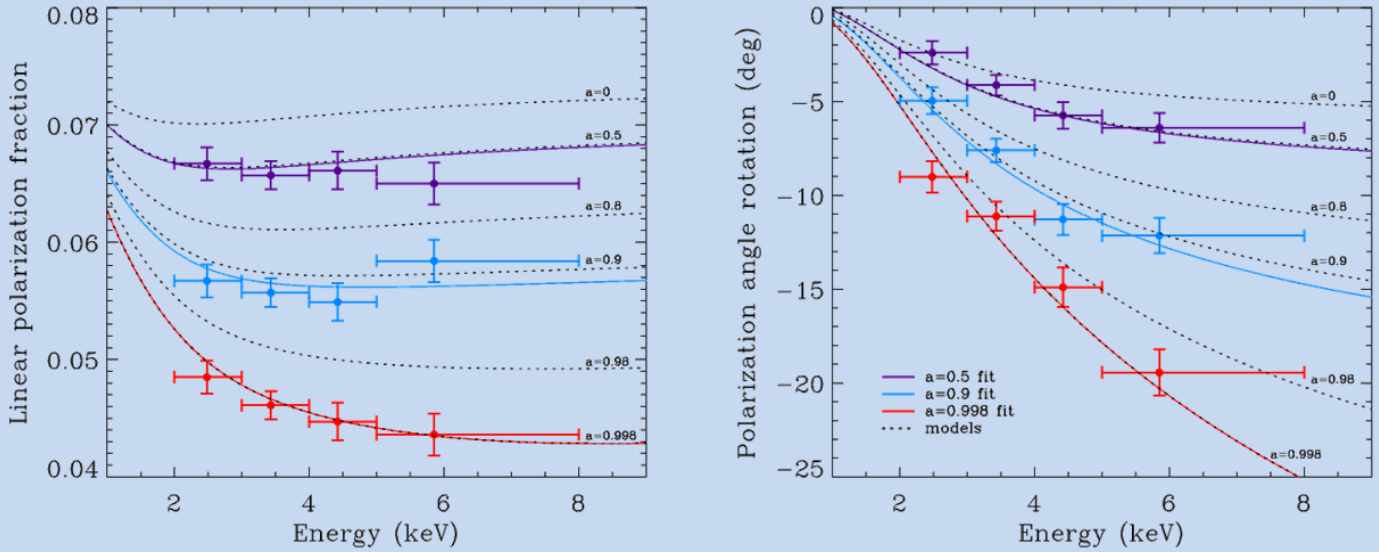
- **Absorption likely more prevalent in visible band.**
- **Radiation process entirely different in radio band.**
  - **Recently discovered *no* pulse phase-dependent variation in polarization degree and position angle @ 1.4 GHz.**
- **140-ks observation gives ample statistics to track polarization degree and position angle.**



MICROQUASARS

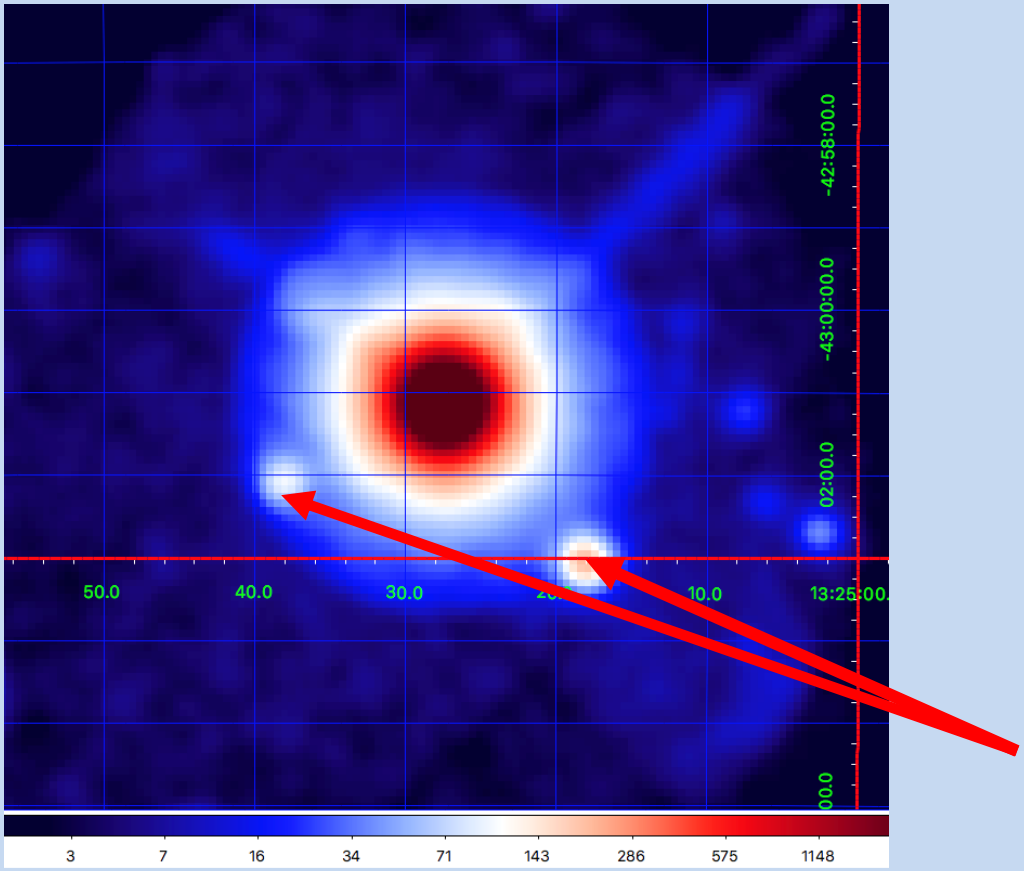
- **Microquasars**
  - **Perform X-ray spectral polarimetry on microquasars to help localize the emission site (accretion disk, corona, jet) position angle**

For a micro-quasar in an accretion-dominated state, scattering polarizes the disk emission.
Polarization rotation versus energy is greatest for emission from inner disk.
– Inner disk is hotter, producing higher energy X-rays.
Disk orientation from other experiments used to constrain GRX1915+105 model.
a = 0.50±0.04; 0.900±0.008; 0.99800±0.00003 (200-ks observation)



ACTIVE GALAXIES: CEN A

- **Active galaxies are powered by supermassive BHs with jets**
  - **Radio polarization implies the magnetic field is aligned with jet**
  - **Different models for electron acceleration predict different dependence in X-rays**

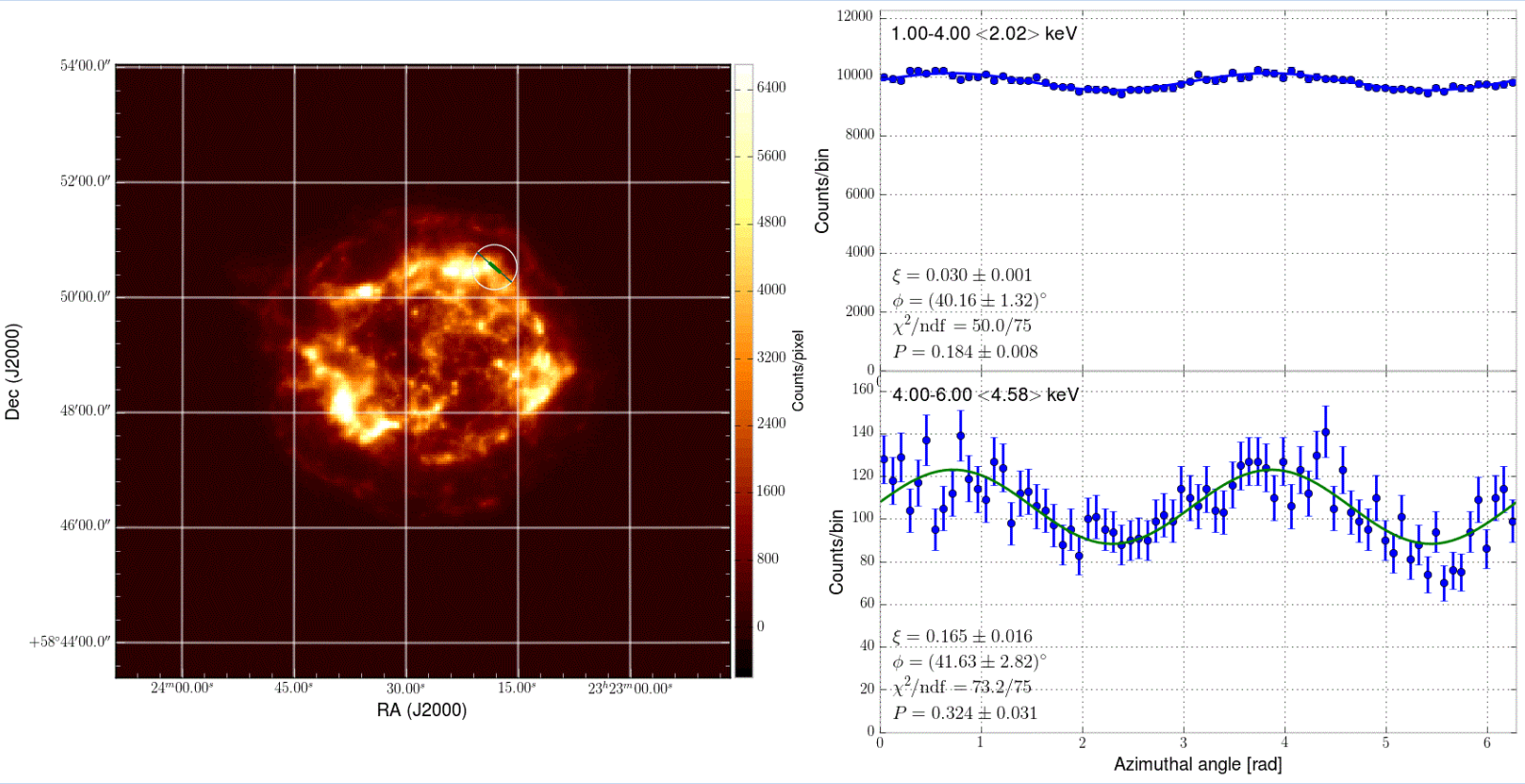


Region	MDP_{99}
Core	1.4%
Knots C+F+G	21%
ULXs	25% 15%

SUPERNOVA REMNANTS

- **Supernova Remnants (SNR – e.g. CAS-A)**
  - **Use X-ray polarmimetric imaging to examine the magnetic-field topology in the X-ray emitting regions of (shell-type) SNR, which are candidate sites for cosmic-ray acceleration (Entire image measured simultaneously)**

Lines and thermal continuum dominate 1-4 keV.
Non-thermal emission dominates 4-6 keV.



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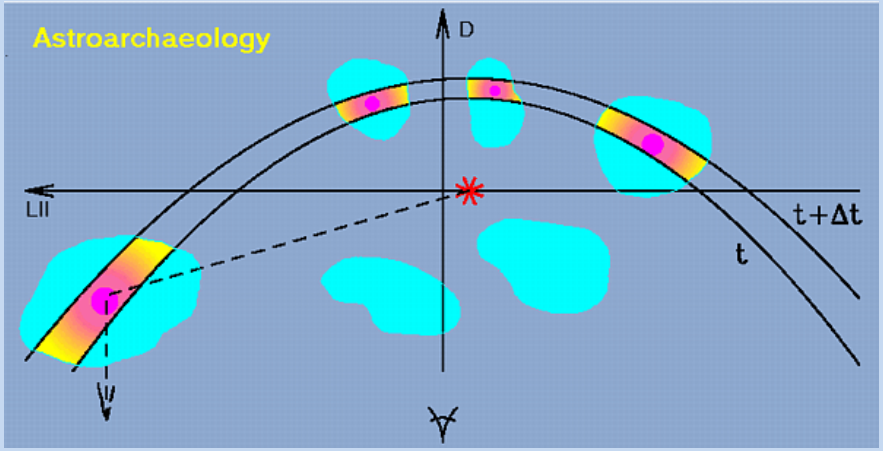
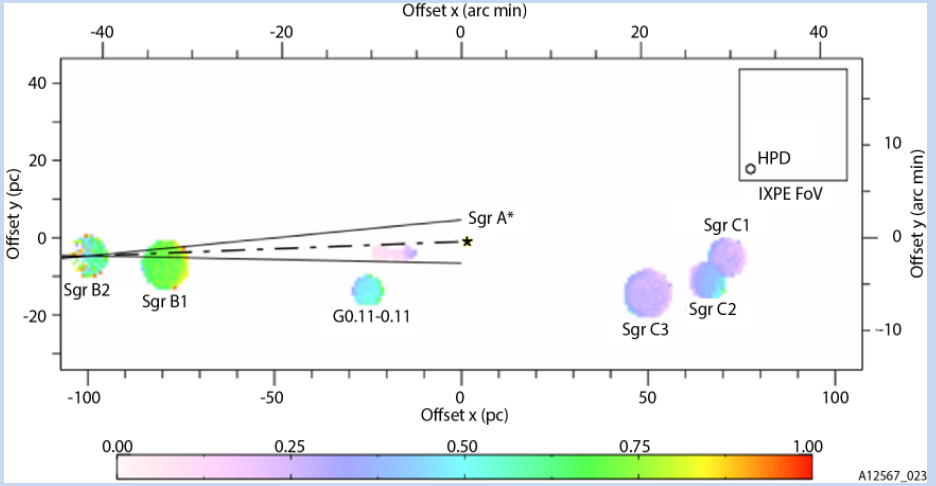
WAS SGR A* RECENTLY 10^6 × MORE ACTIVE?

- **Galactic Center molecular clouds (MC) are known X-ray sources**
  - **If the MCs reflect X-rays from Sgr A* the X-radiation would be highly polarized perpendicular to plane of reflection and indicates the direction back to Sgr A***
    - **If true, Sgr A* X-ray luminosity was 10^6 larger ≈ 300 years ago**
    - **If not, still a discovery**





TEST QED

- **Study Magnetars (pulsing neutron stars with magnetic fields up to 10^{15} Gauss)**
  - **Non-linear QED predicts magnetized-vacuum birefringence**
    - **Refractive indices of the two polarization modes differ from 1 and from each other**
    - **Impacts polarization and position angle as functions of pulse phase, but not the flux**
    - **Example is 1RXS J170849.0-400910, with an 11-s pulse period**
    - **Can exclude QED-off at better than 99.9% confidence in 250-ks observation**