IXPE
Imaging
X-Ray
Polarimetry
Explorer

The Imaging X-ray Polarimetry Explorer

Martin C. Weisskopf on behalf of the IXPE team

NASA/Marshall Space Flight Center

X-ray Astronomy 2019

September 13, 2019, Bologna, Italy

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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 April 2021 on a Falcon 9
- > 540-km circular orbit at 0° inclination
- 2-year baseline mission, 1 year extension (at least!)
- 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
- Sciences Operations Center at MSFC
- Data archiving at NASA's HEASARC
  - No proprietary data

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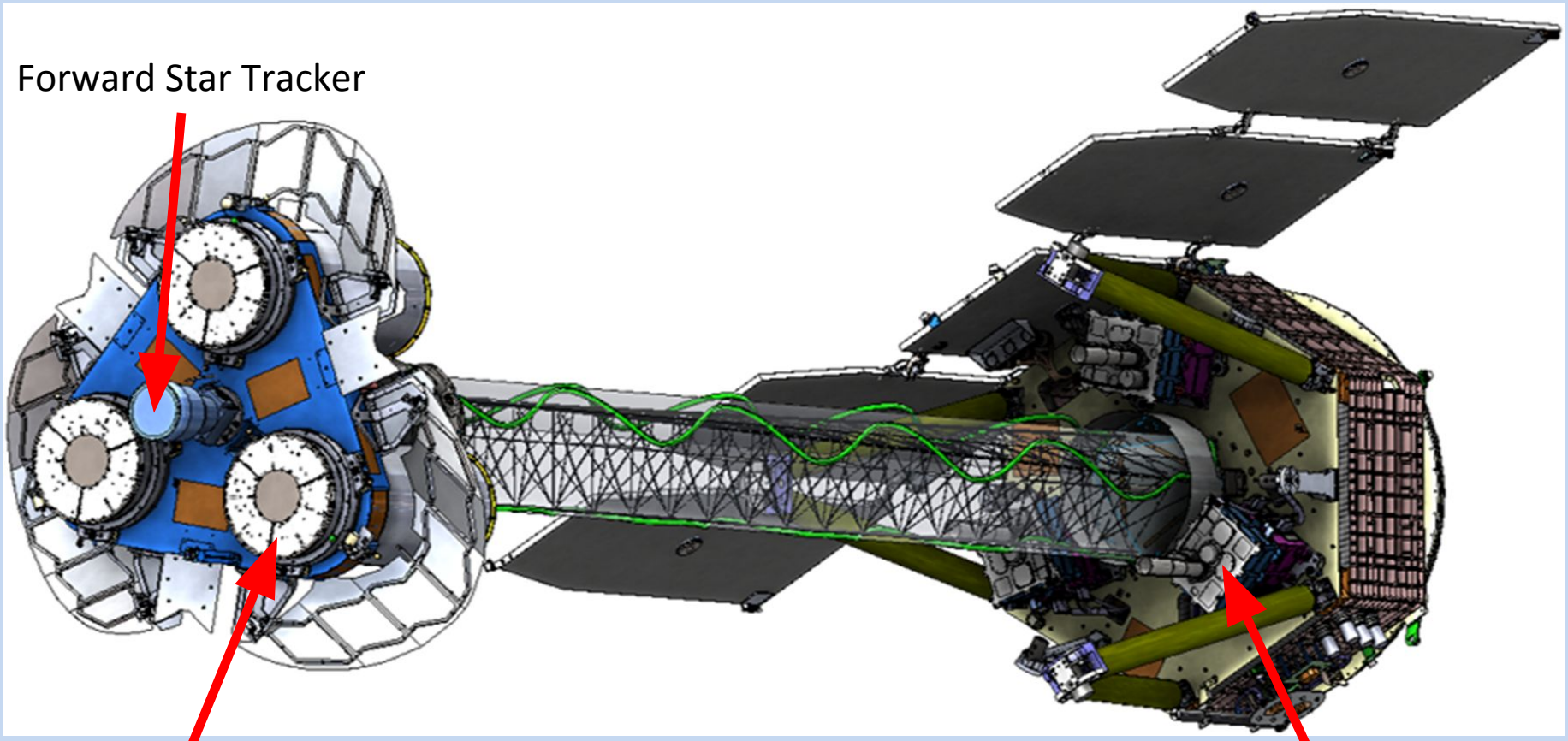
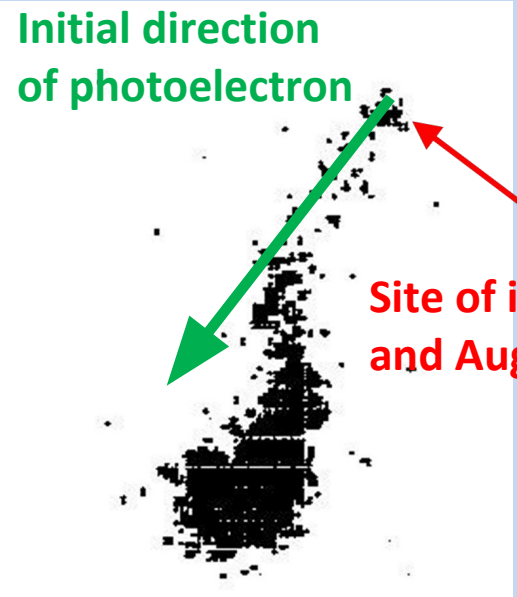
IXPE Deployed

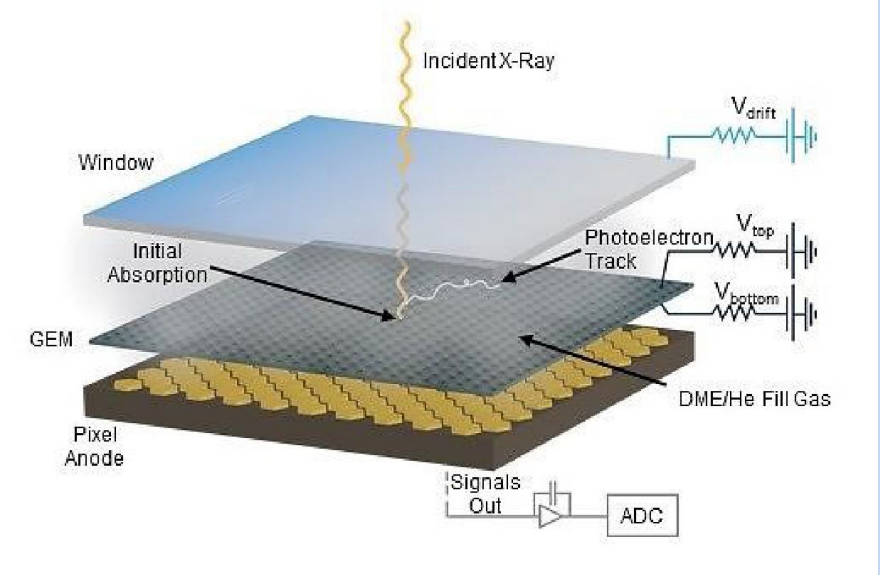


5.2 m total length
4.0 m focal length

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

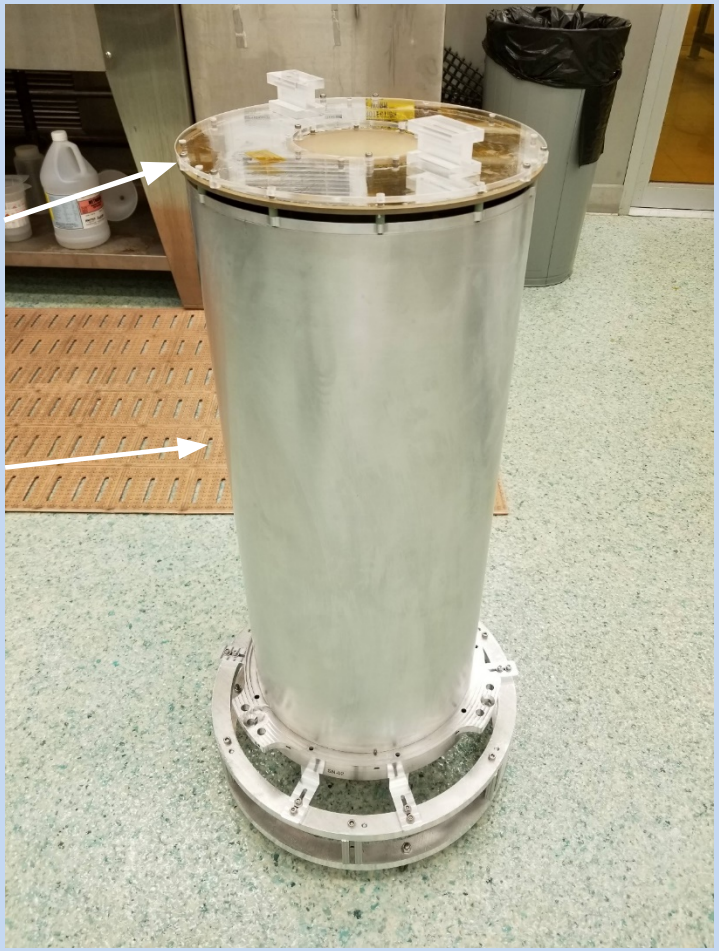
Inner shells (3)

Mass Simulators

Front Spider

Thermal Shields

Outer Housing



Measured angular resolution 20 arcsec @ 2.3 and 4.5 keV

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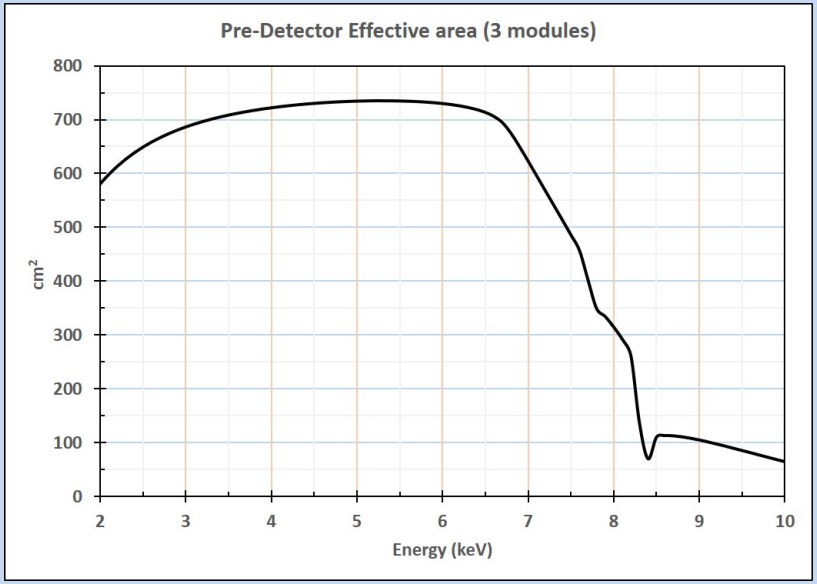
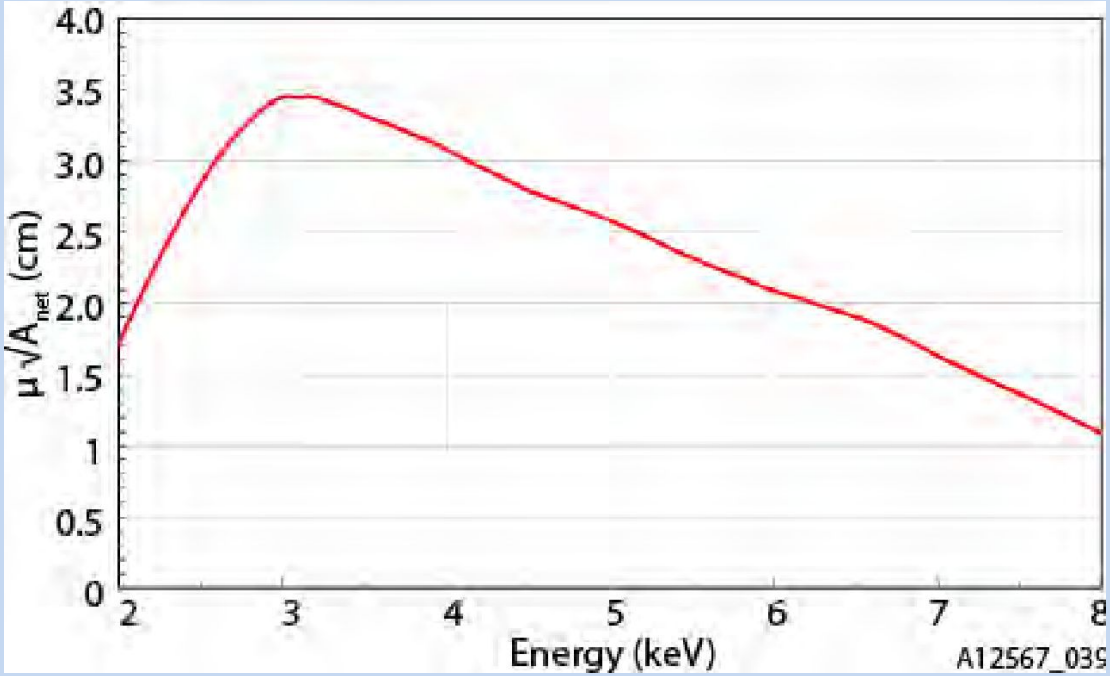
Mirror Module Assembly

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

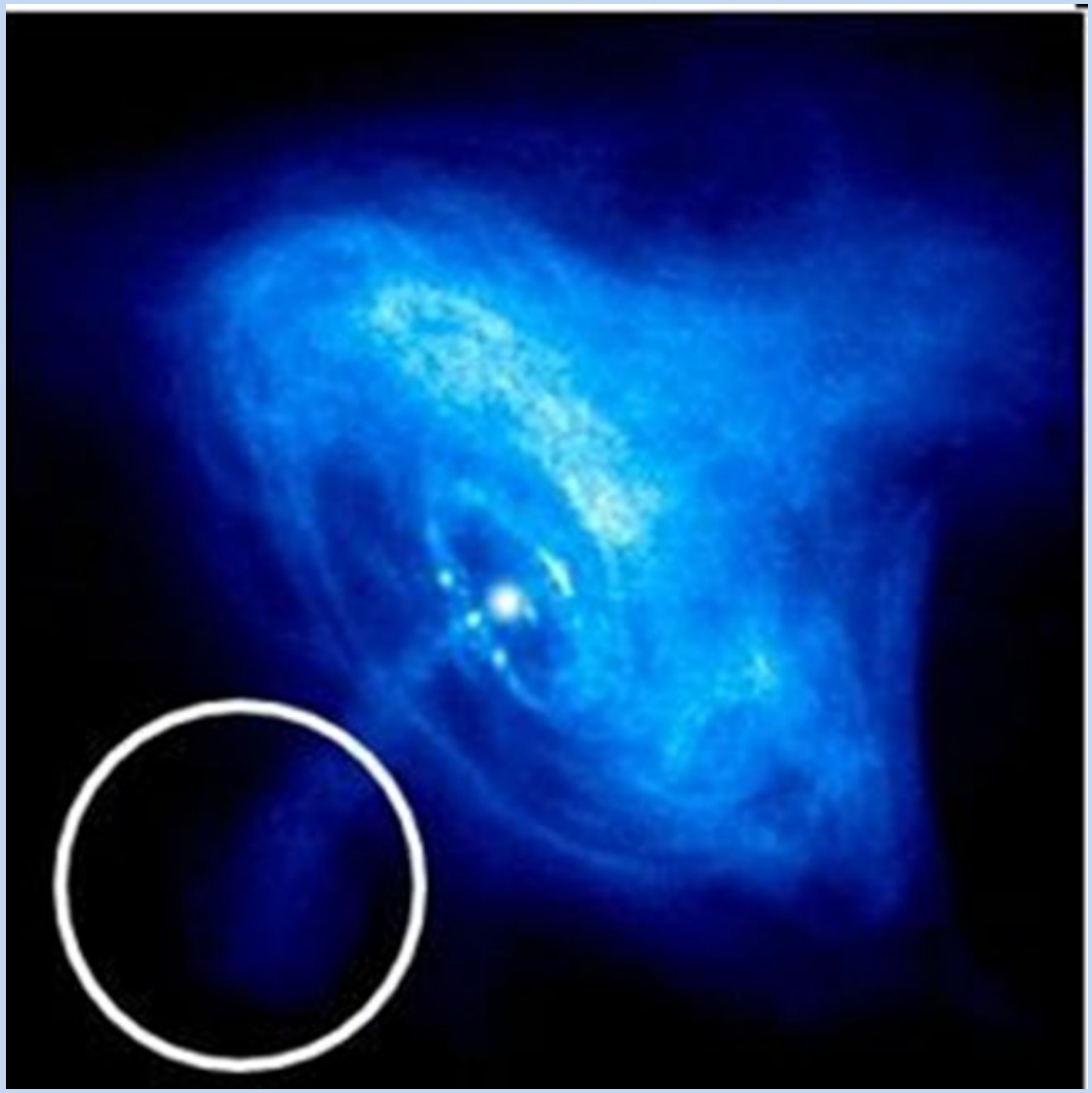


POLARIZATION SENSITIVITY FIGURE OF MERIT



IMAGING POLARIMETRY

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



RADIO PULSARS

Radio Pulsars

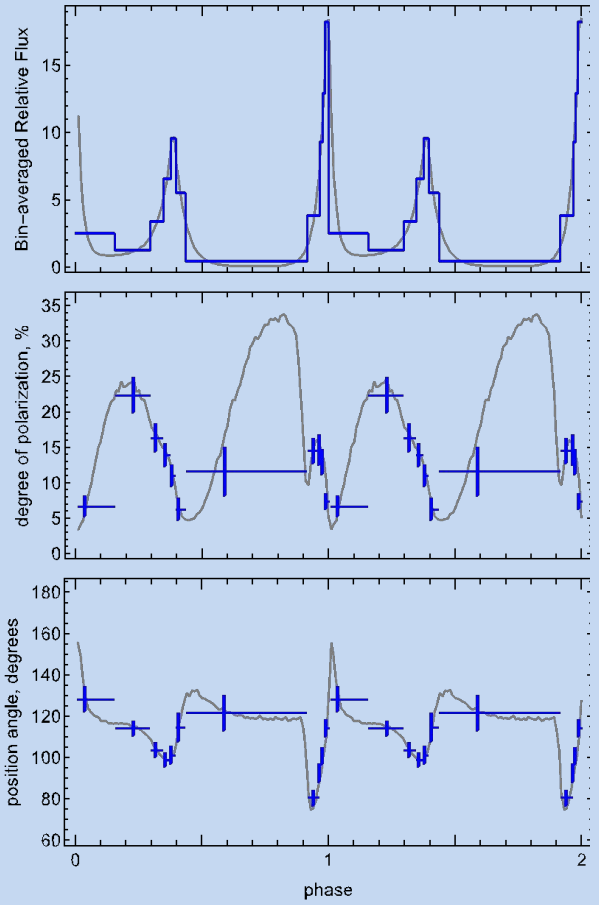
- Perform X-ray phase-resolved polarimetry to test models for a radio pulsar's X-ray emission
- Grey is optical, blue is IXPE

Emission geometry and processes are still unsettled.

- Competing models predict differing polarization behavior with pulse phase.

X-rays provide clean probe of geometry.

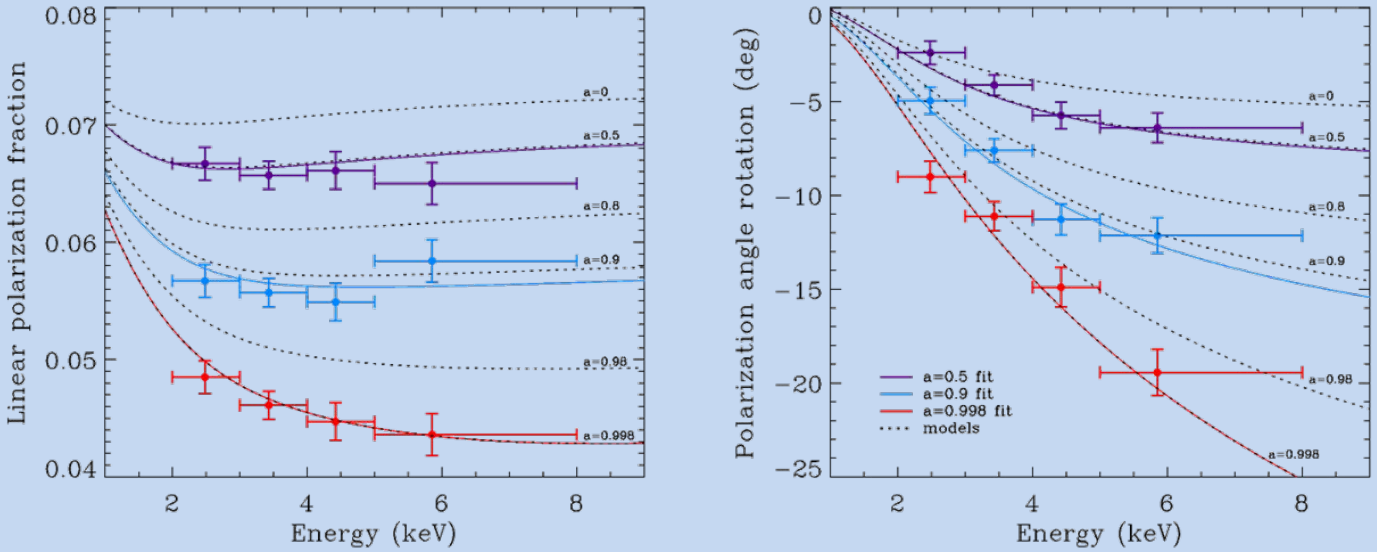
- Absorption likely more prevalent in visible band.
- Radiation process entirely different in radio band.
  - Recently discovered ***no*** pulse phase-dependent variation in polarization degree and position angle @ 1.4 GHz.
- 140-ks observation gives ample statistics to track polarization degree and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



MICROQUASARS

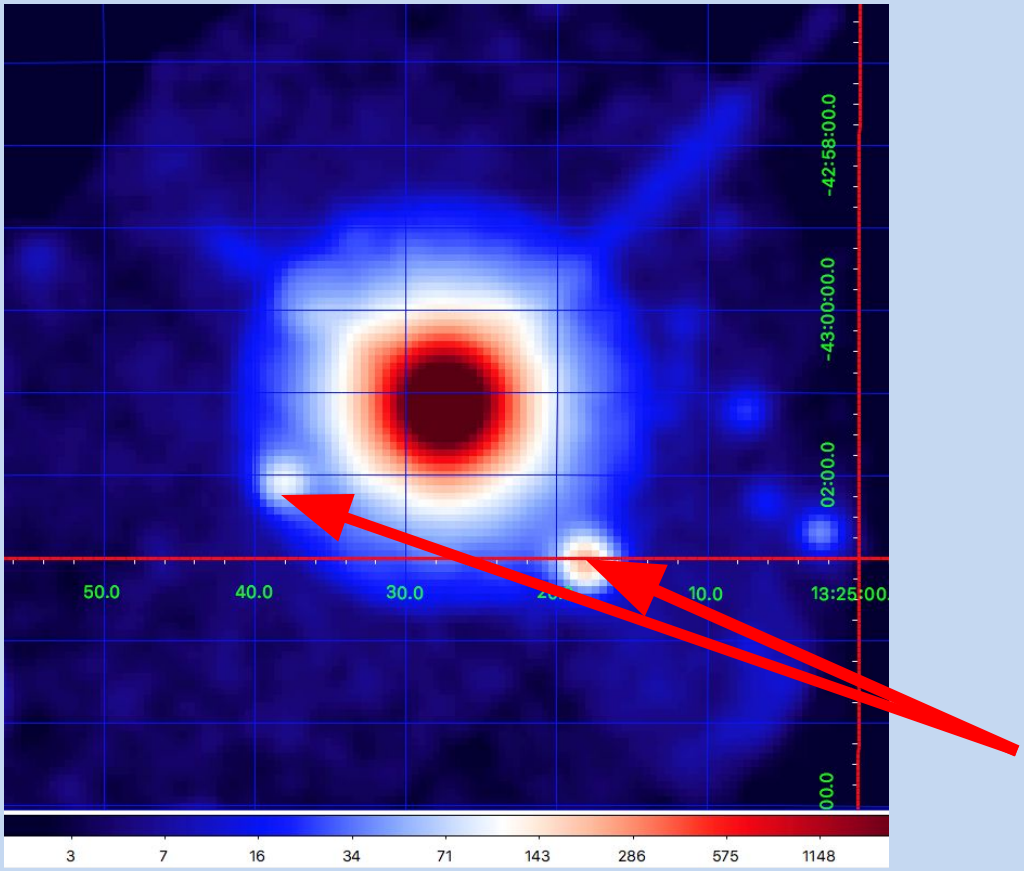
- **Microquasars**
  - **Perform X-ray spectral polarimetry on microquasars to help localize the emission site (accretion disk, corona, jet) position angle**

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%**

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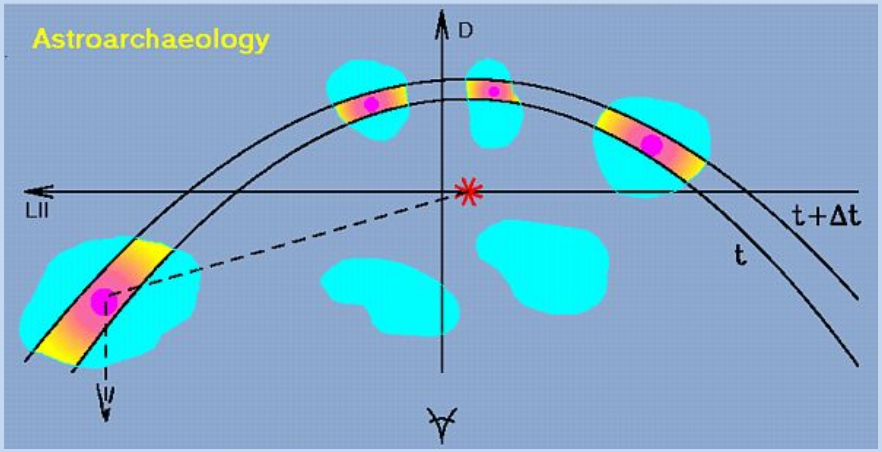
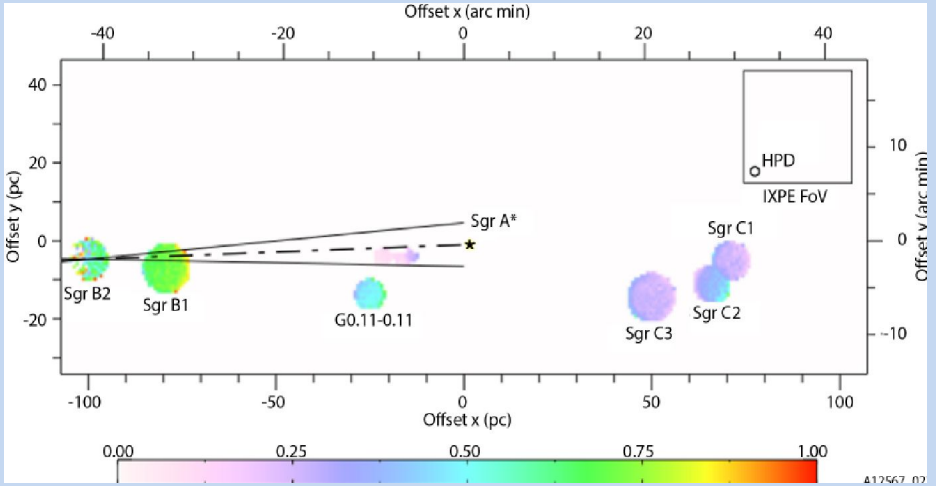
WAS SGR A* RECENTLY 10^6 × MORE ACTIVE?

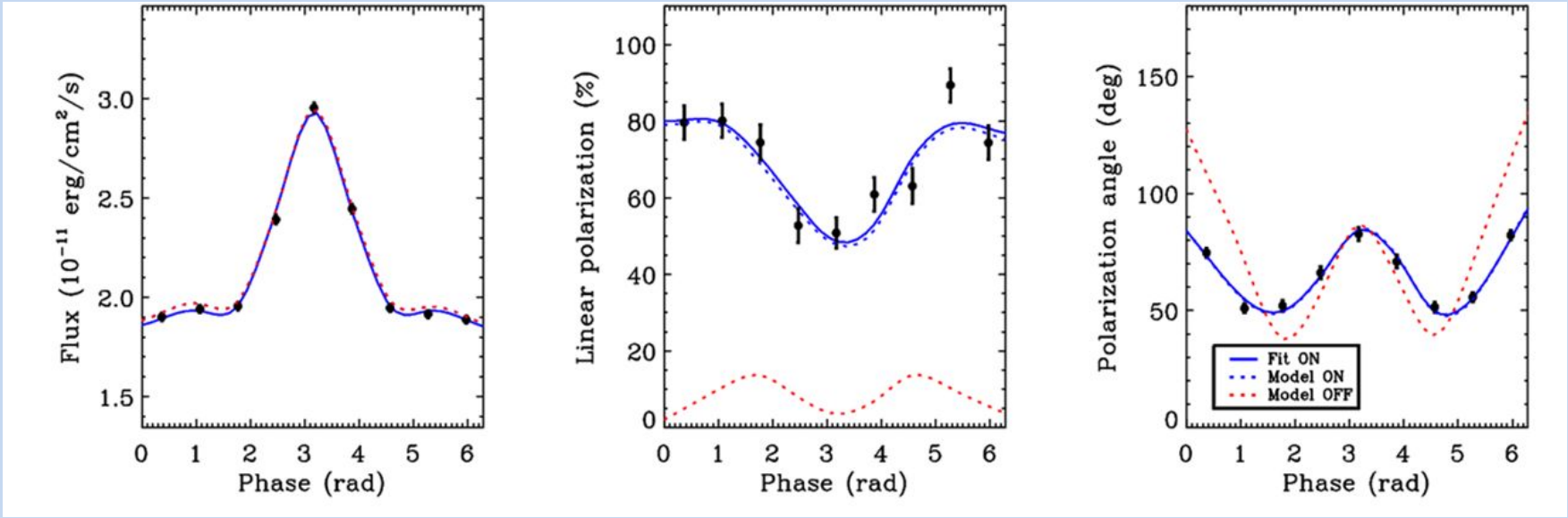
- **Galactic Center molecular clouds (MC) are known X-ray sources**
  - **If the MCs reflect X-rays from Sgr A* the X-radiation would be highly polarized perpendicular to plane of reflection and indicates the direction back to Sgr A***
    - **If true implied Sgr A* X-ray luminosity was 106 larger ≈ 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**



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