THE *IMAGING* X-RAY POLARIMETRY EXPLORER (IXPE)

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The Core Science Team

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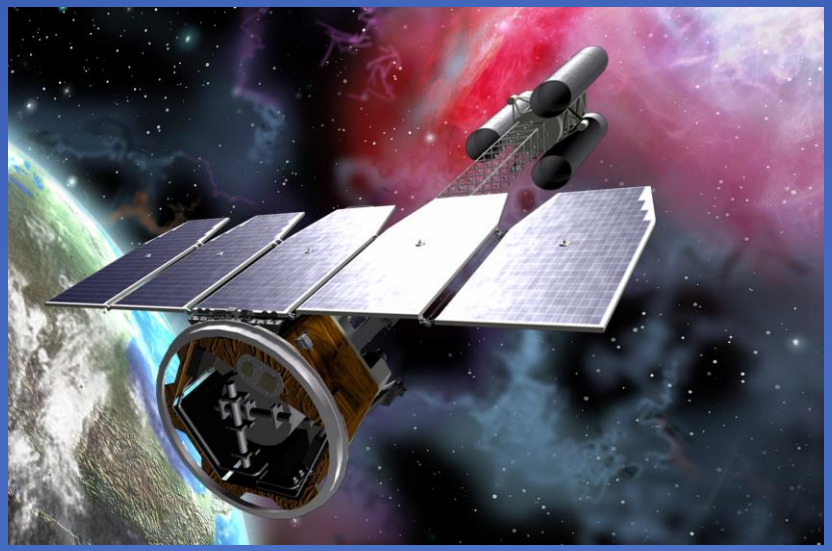
Herman Marshall (MIT) – Co-I & Student Collaboration Lead
Giorgio Matt (Univ Roma Tre, IT) – Co-I & Theory Lead
Roger Romani (Stanford) – Co-I & Theory Lead

Enhanced Capability

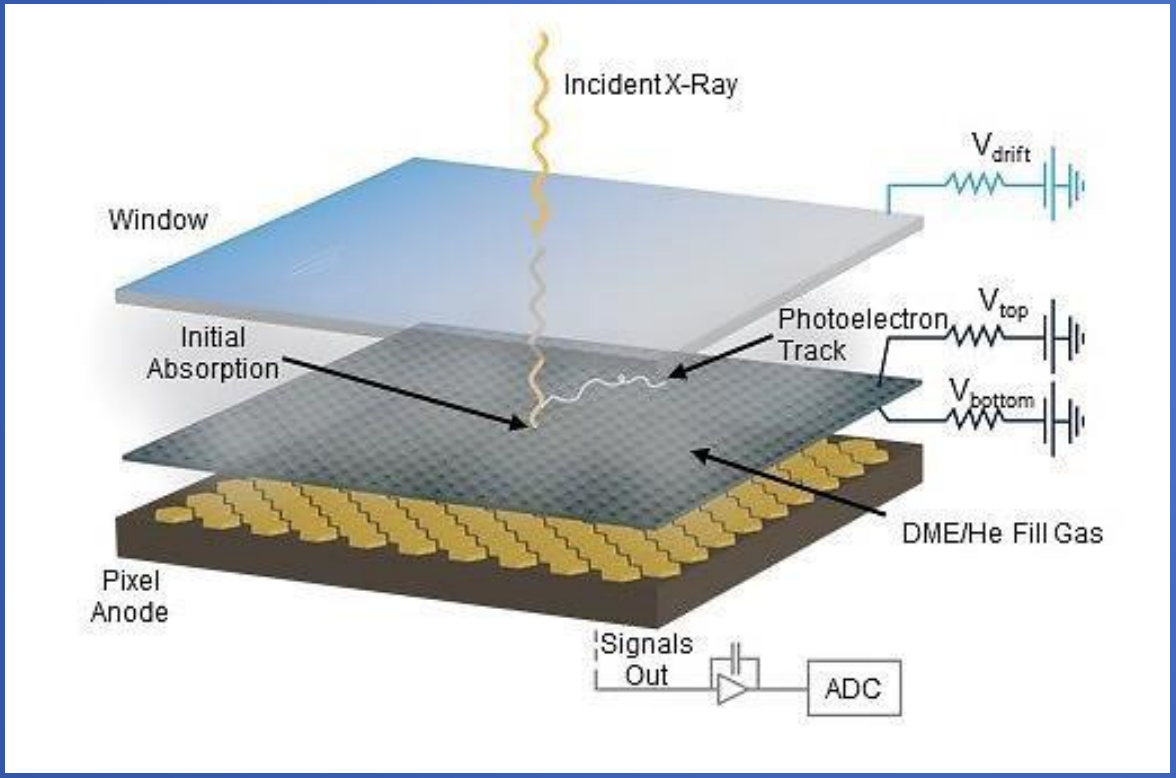


- X-ray sources very suitable for polarimetry as they often involve
  - Aspherical emission/scattering geometries
  - Non-thermal processes
  - Strong fields
- Provides increased sensitivity by factor of >100 over OSO-8
- Dramatically expands observation space to provide new input and constraints to our understanding of astrophysical systems

Electron Tracking

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

$$\frac{d\sigma}{d\Omega} \propto \sin^2\theta \cos^2\varphi$$

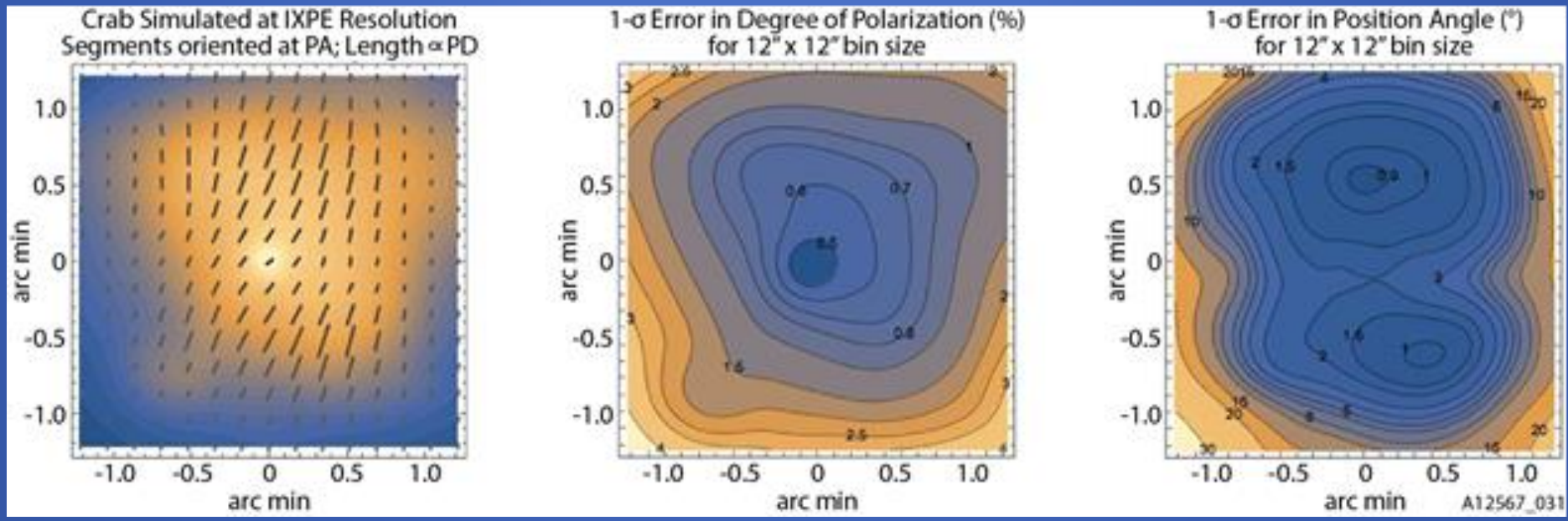


Site of initial ionization

- Azimuthal symmetry minimizes/eliminates systematic effects

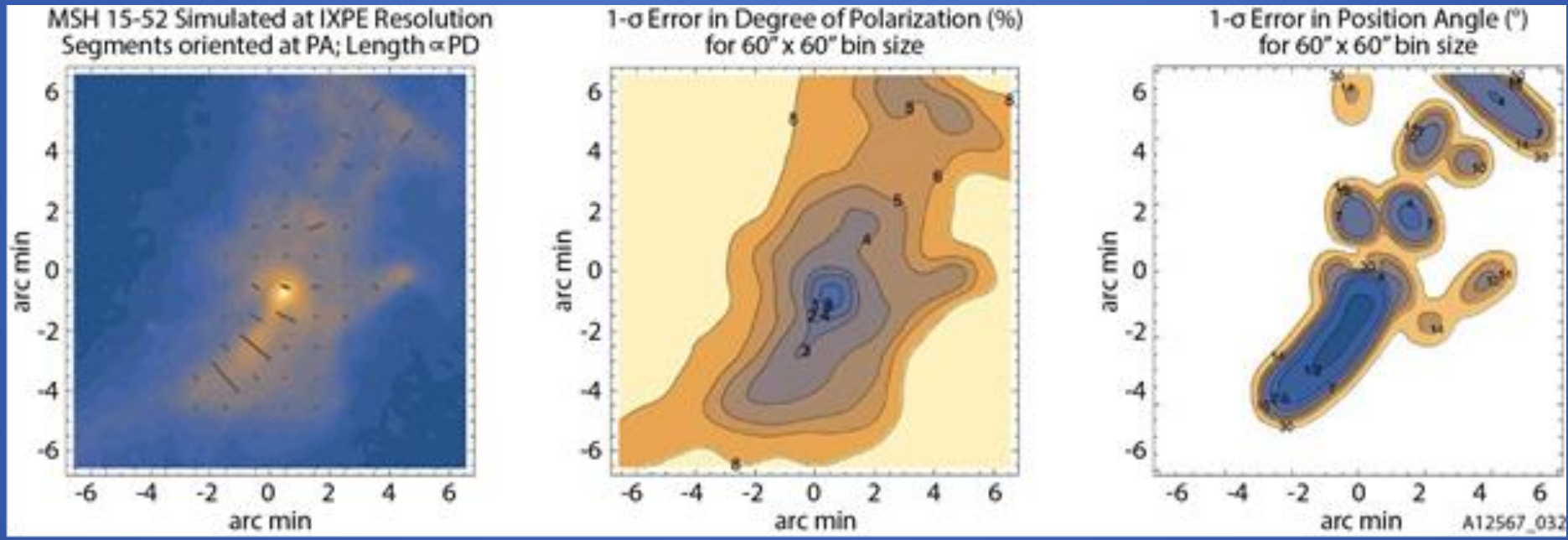
Polarization Maps of Pulsar Wind Nebulae
The Crab Nebula

- Map the magnetic field of the X-ray-emitting regions
- Importance emphasized by the discovery of gamma-ray flares from the Crab Nebula (not the pulsar!)
- Model based on optical polarization maps applied to the Chandra image convolved with our telescope response



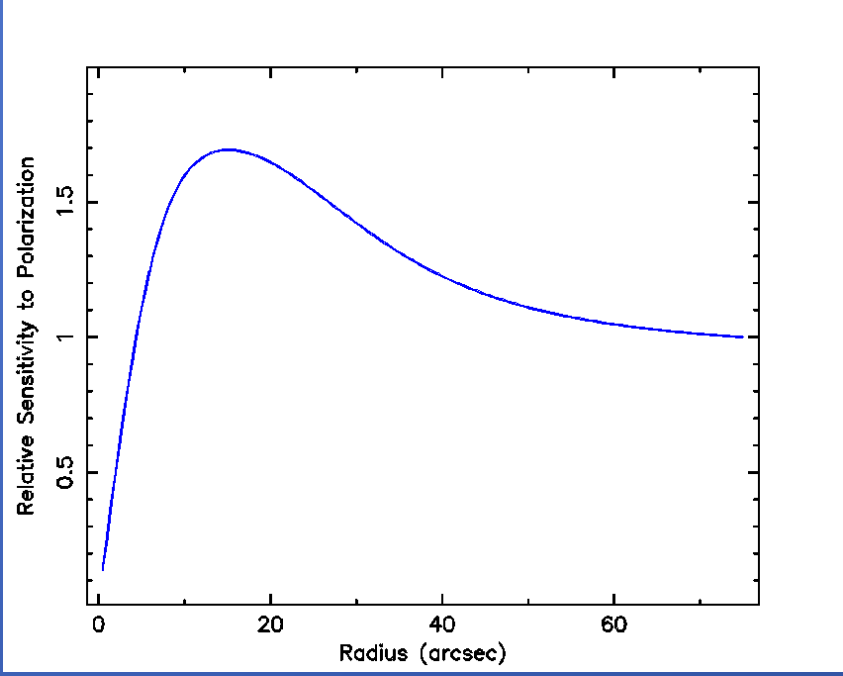
Polarization Maps of Pulsar Wind Nebulae
MSH 15-52

- Convolved Chandra image of MSH 15-52 with IXPE response
- Imaging polarimetry maps the magnetic field in this rather extended and complex PWN
- As an example, consider a model of the core, jet, & “hand”
  - Longitudinal B along the jet, ~60% polarized
  - Other regions 10%-20% polarized



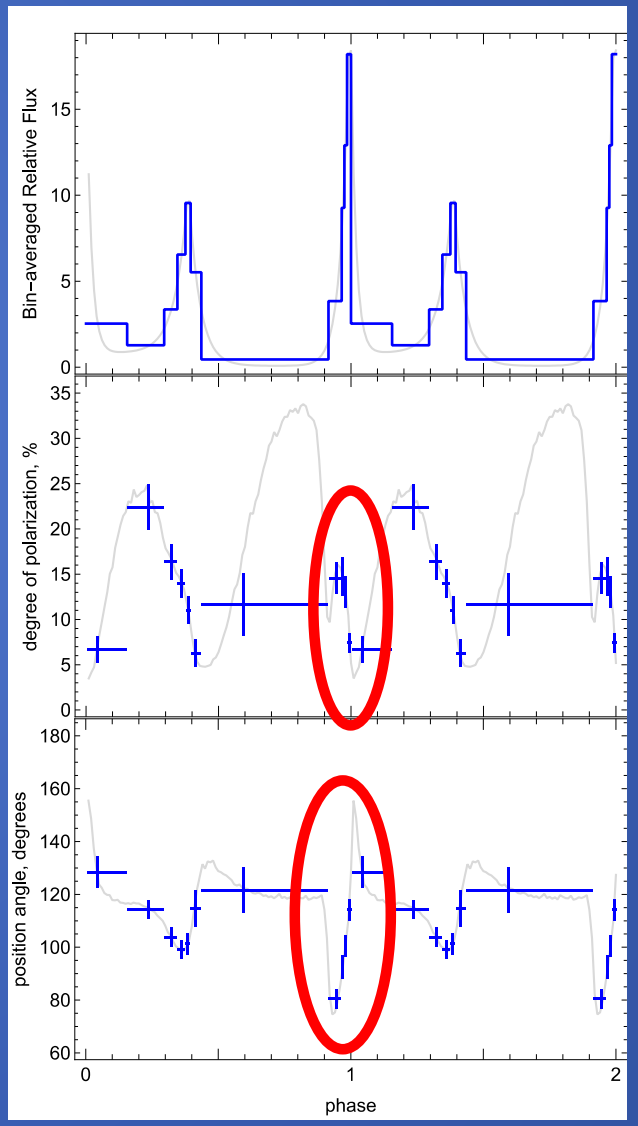
Radio pulsars

- Exploit imaging to perform meaningful polarization measures for the X radiation from pulsars in PWNe
  - Addresses the orientation of the rotation axis and inclination of the magnetic field
- Expect surprises as we recently found at 1.38 GHz for the Crab's pulsar
  - The position angle does ***NOT*** vary through either the primary or interpulse
- Imaging improves Crab pulsar sensitivity by a factor of 1.7
  - Equivalent to increasing the effective area by 2.9
- For MSH15-52 the factor is 2.8
  - Makes observation feasible



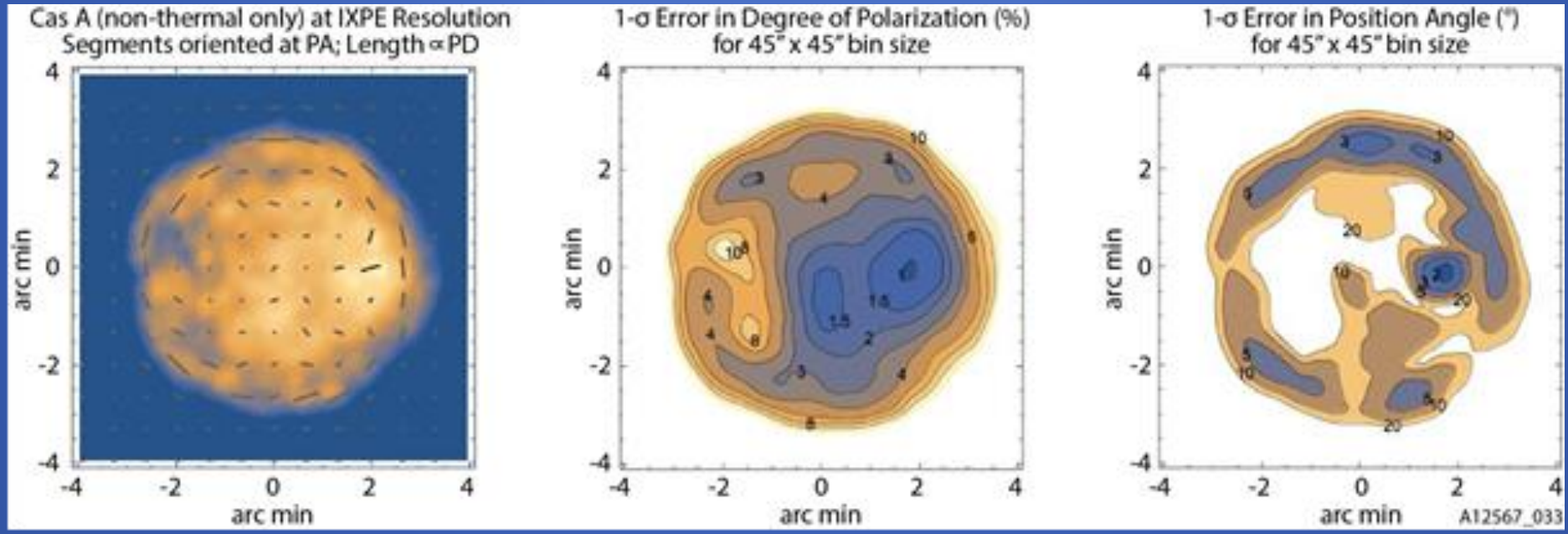
Phase-dependent polarimetry - Crab

- Divide pulse into 12 bins of ~ equal pulsed counts
  - Grey indicates the optical polarization measurement
  - Blue indicates the errors in the X-ray polarization measurement accounting for the contribution of the nebula



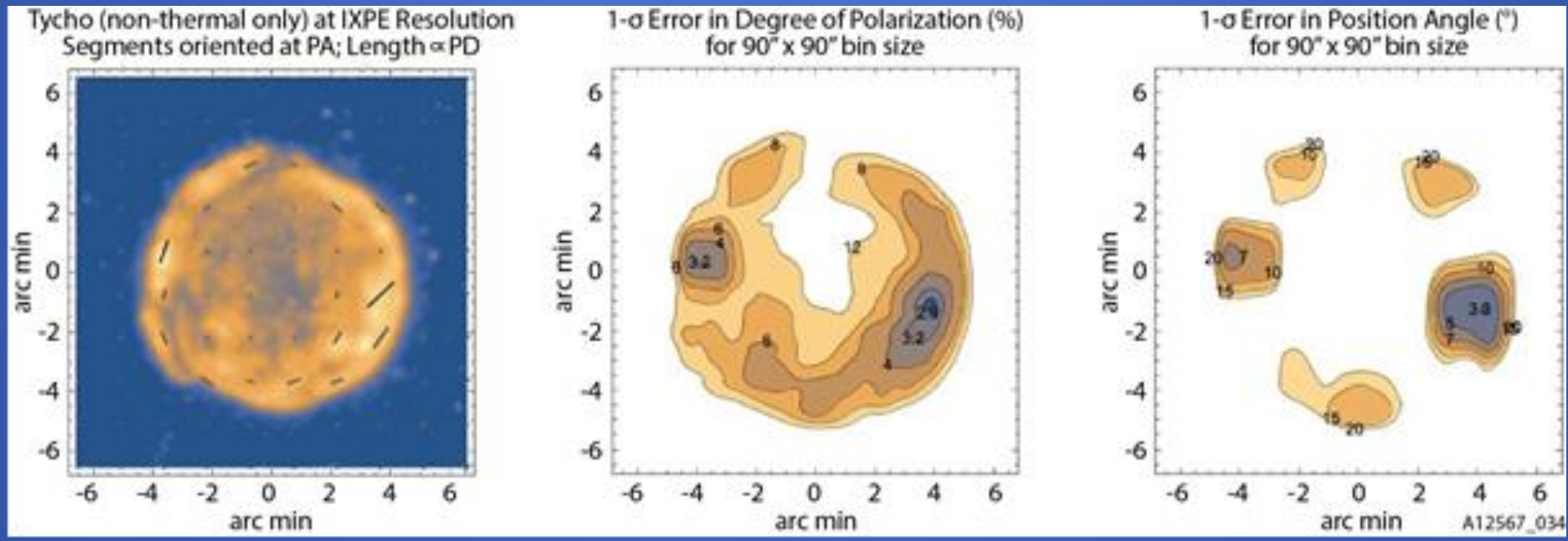
Supernova remnants – Cas A

- Perform image-resolved polarimetry of sites of particle acceleration in shell-type supernova remnants
- Spectral imaging allows one to separate the thermalized plasma from the regions where shocks accelerate particles
- Map to left is based on the total X-ray flux
- Middle and right are the sensitivity for the non-thermal component accounting for dilution by the thermal component



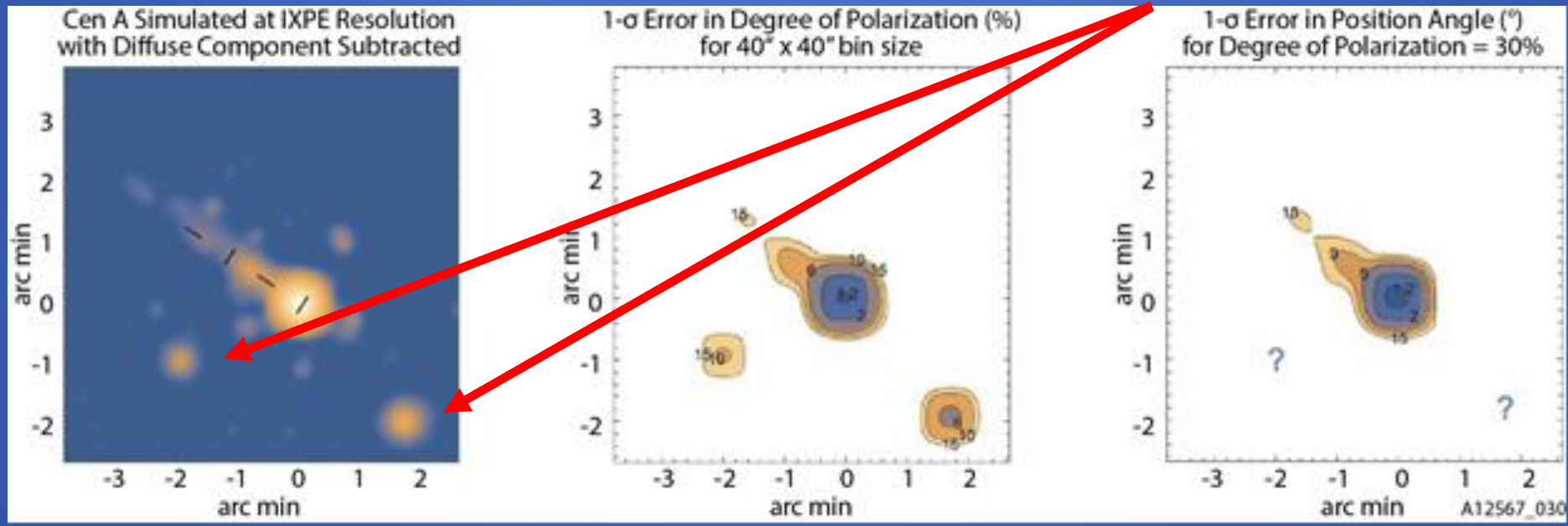
Supernova remnants - Tycho

- Image-resolved polarimetry of sites of particle acceleration in shell-type supernova remnants
- Map to left is based on the total X-ray flux
- Middle and right take account of dilution by the thermal component
- High-resolution X-ray images indicate stripes to the south-west which IXPE cannot resolve but will detect their polarization



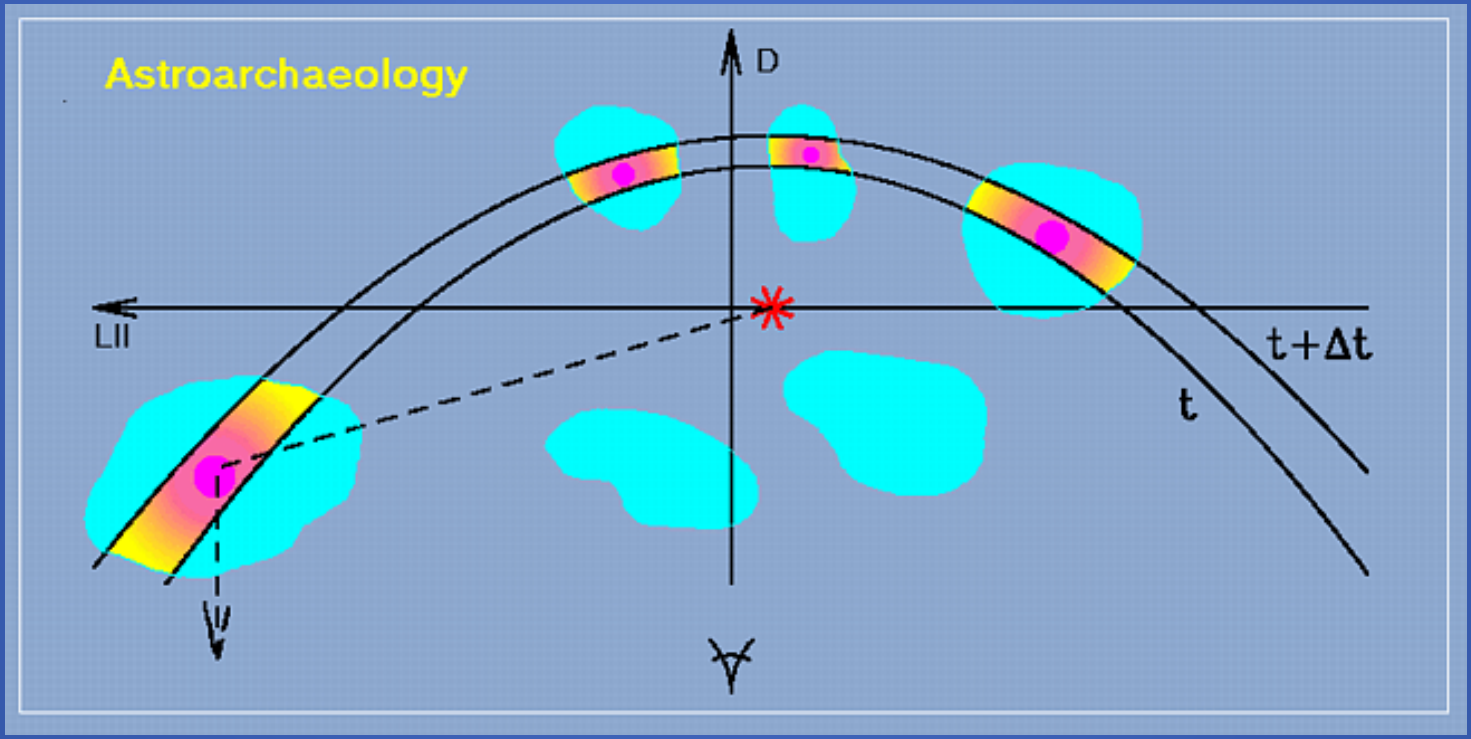
Active galaxies and their jets – Cen A

- Map the magnetic field of resolved X-ray emitting jets close to the injection point of the electrons
- Convolved Chandra image of Cen A with IXPE response
- Constructed a plausible model
  - Transverse B in hot spots (shocks) along the jet
  - Longitudinal B between hot spots and in the core
  - Assumed 30% polarization to estimate position-angle error
- Imaging allows us to simultaneously pick up ULXs in the field



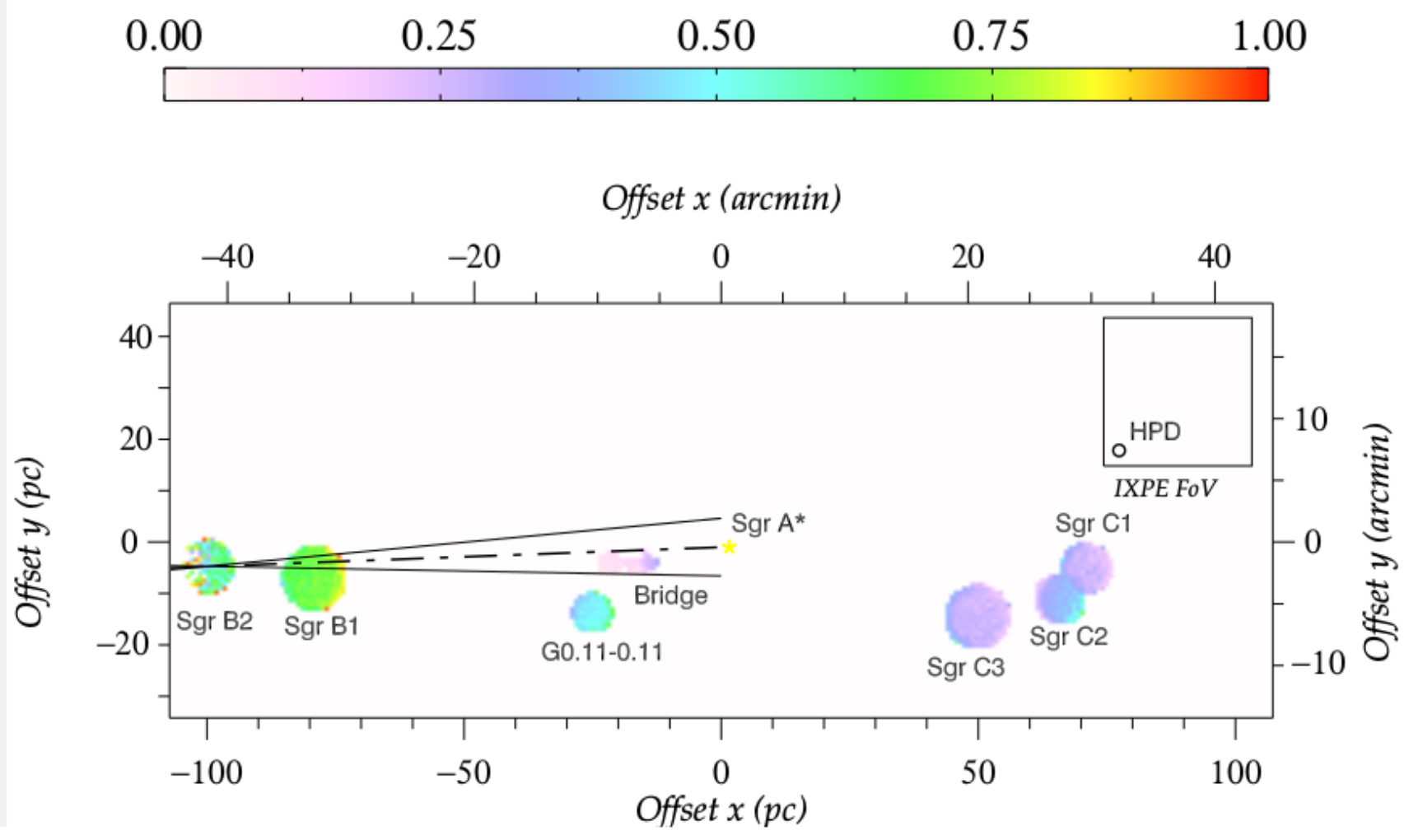
Probing the Galactic Center

- Demonstrating past activity from SGR A* through polarization measurements of the X-ray flux from nearby molecular clouds
- The degree of polarization is related to the source-cloud-observer (scattering) angle



Probing the Galactic Center - II

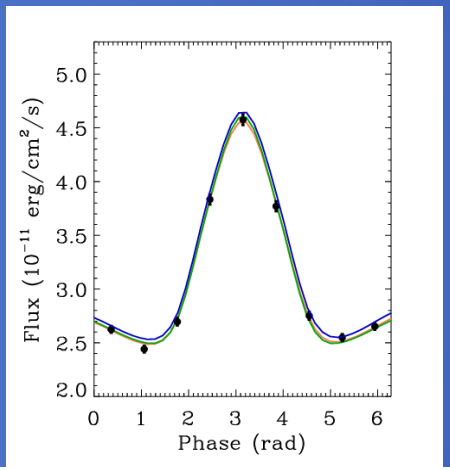
- The position angle is perpendicular to the source direction

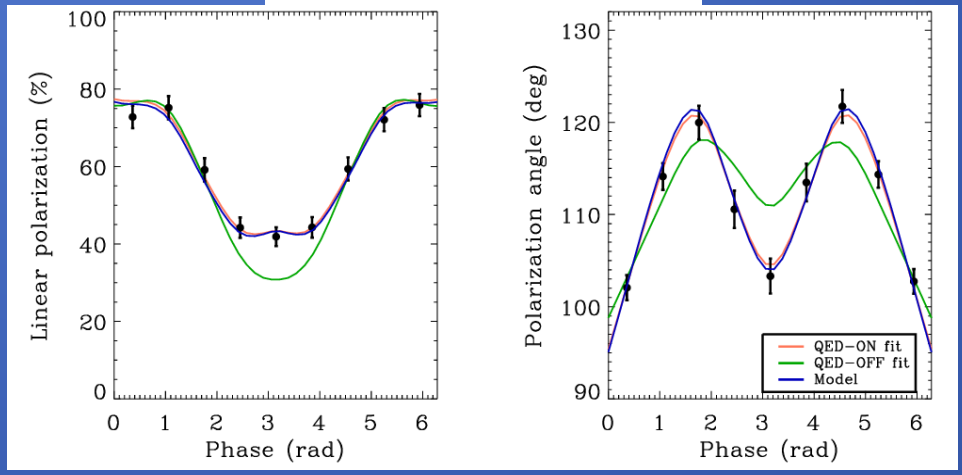


Expansion of Measurements over OSO-8

- Perform astrophysical meaningful measurements for a variety of classes of X-ray sources (energy bins, spatial bins, time bins)
- Hundreds of targets to choose from
- For example, test QED in the ultra-strong magnetic field in magnetars

Category
PWNe + PSR
SNR
MAGNETAR
CLASSICAL ACCRETING XRB
LMXB/AMSP
MICRO-QSO BH BINARY
GALACTIC CENTER
AGN
ULX



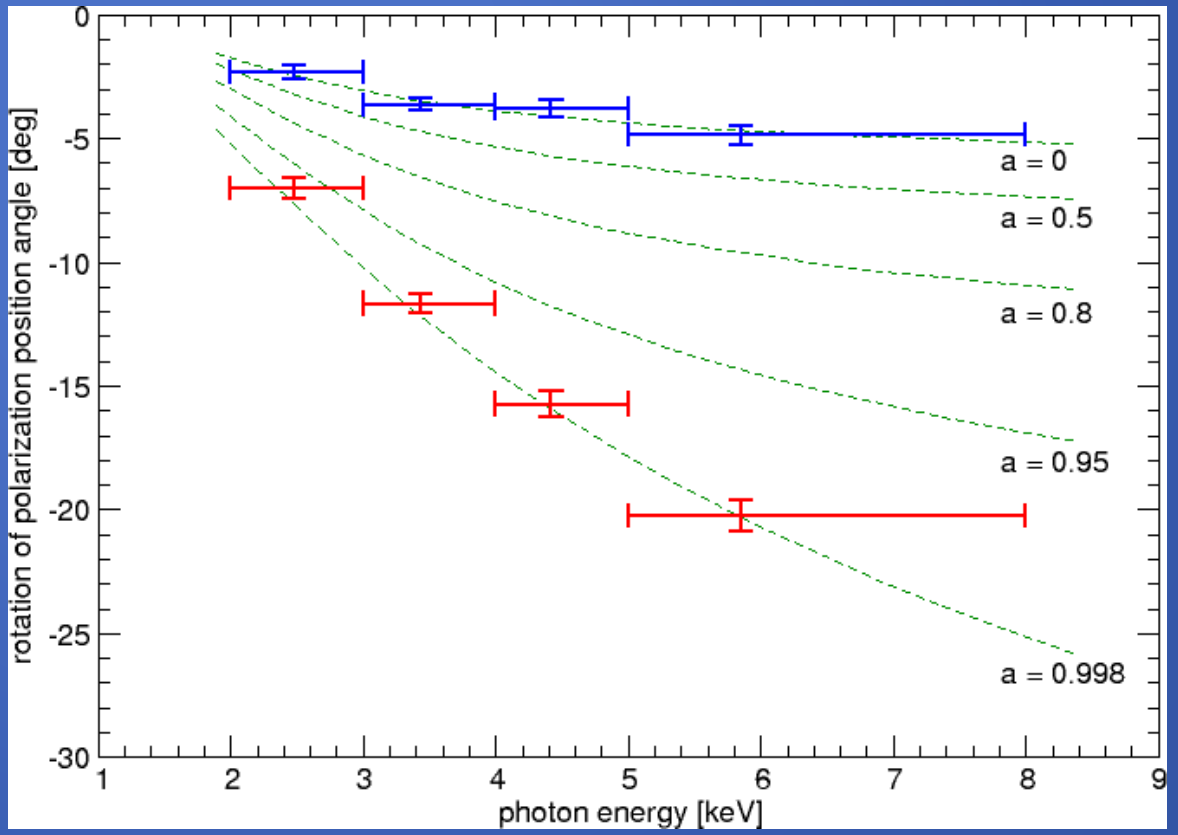


Expansion of Measurements over OSO-8

- Perform astrophysical meaningful measurements for a variety of classes of X-ray sources
- For example, measure black-hole spin in micro-quasars

Category
PWNe + PSR
SNR
MAGNETAR
CLASSICAL ACCRETING XRB
LMXB/AMSP
MICRO-QSO BH BINARY
GALACTIC CENTER
AGN
ULX

GRS 1915-105



Thank you