

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

An Overview

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On behalf of the IXPE team

The Core Science Team

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Paolo Soffita (IAPS, IT) – Co-I and PI for the Italian effort

Ronaldo Bellazzini (INFN, IT) – Co-I and PI for INFN effort

Enrico Costa (IAPS, IT) – Senior Co-I & Consigliere

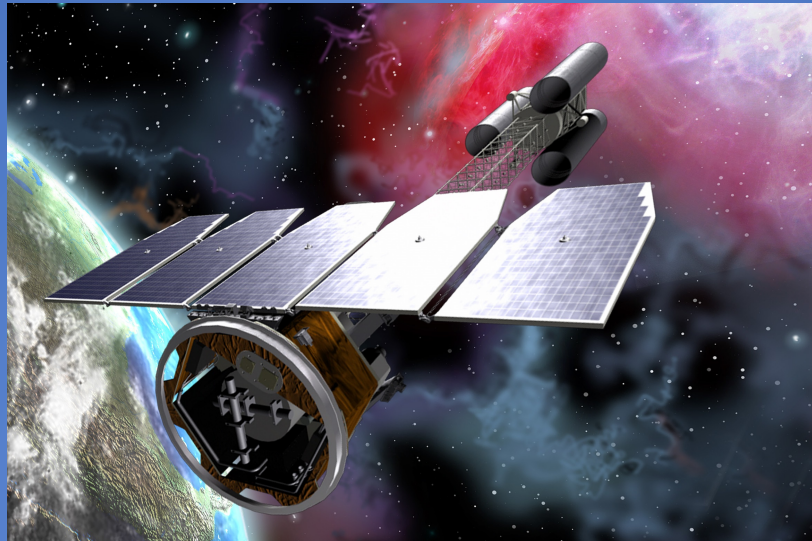
Victoria Kaspi (McGill, Can) – Co-I & SWG Chair

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

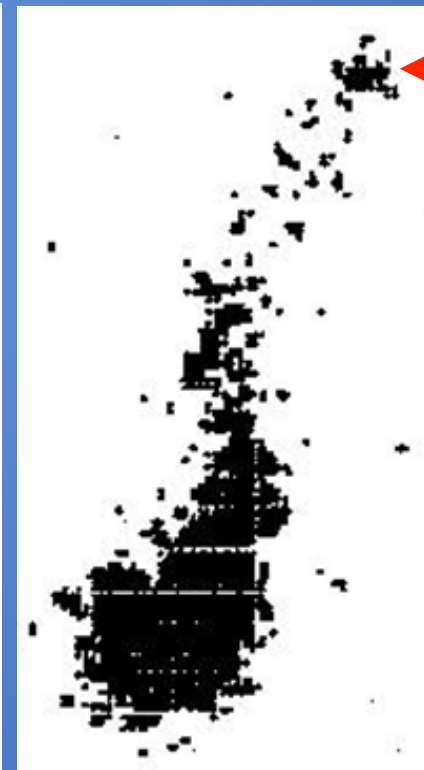
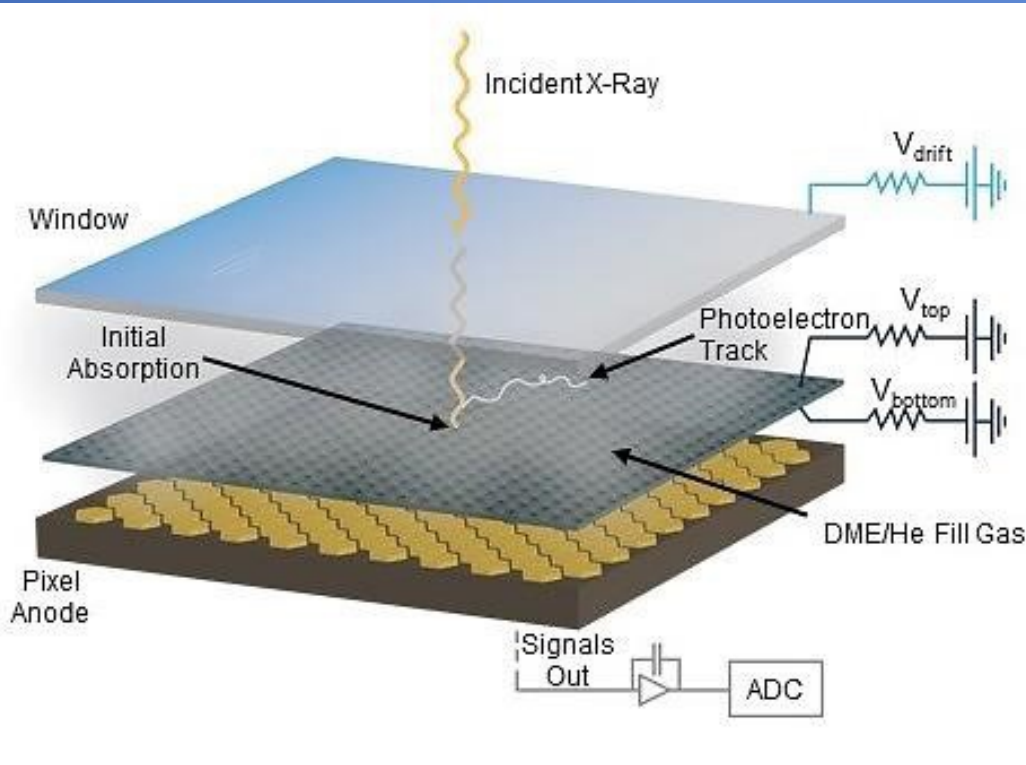


- X-ray sources very suitable for polarimetry as they often involve
 - Aspherical emission/scattering geometries
 - Non-thermal processes
 - Strong fields
- Provides increased sensitivity by factor of >100
- Dramatically expands observation space to provide new input and constraints to our understanding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

$$d\sigma/d\Omega \propto \sin^2 \theta \cos^2 \varphi$$



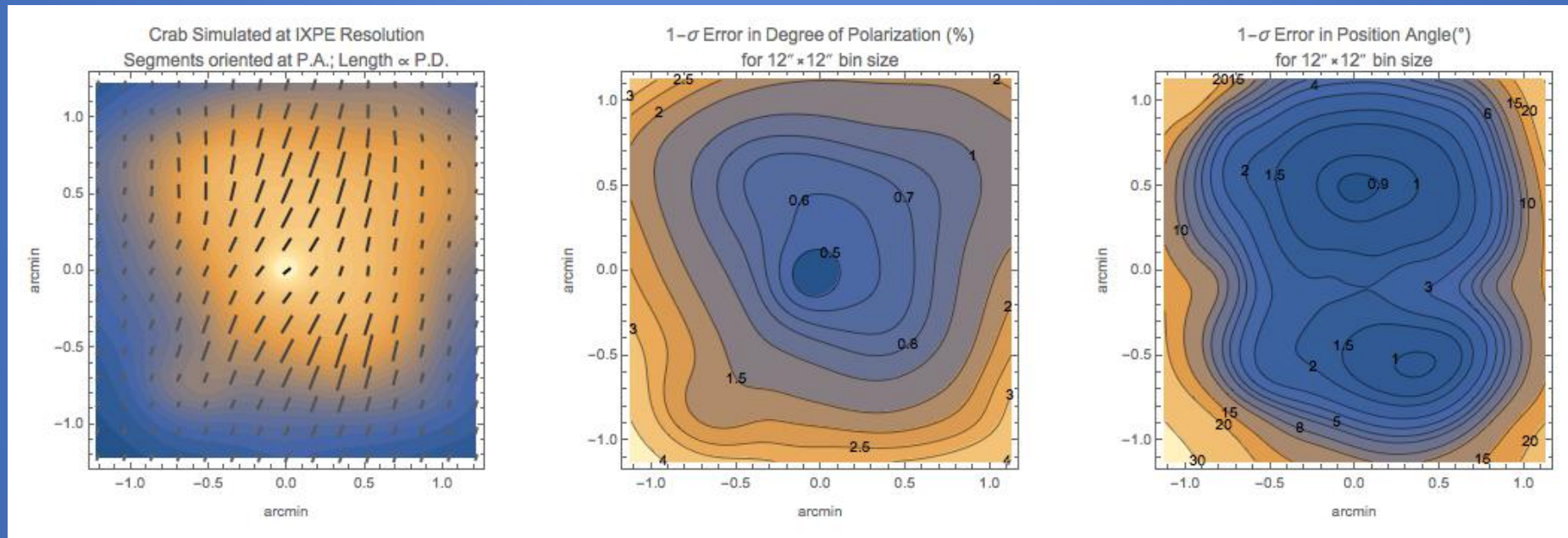
- Azimuthal symmetry minimizes/eliminates systematic effects

Polarization Maps of Pulsar Wind Nebulae

The Crab Nebula

5

- 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

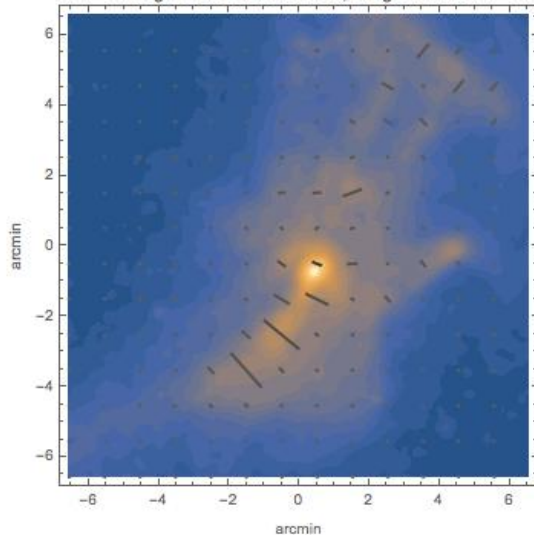


Polarization Maps of Pulsar Wind Nebulae

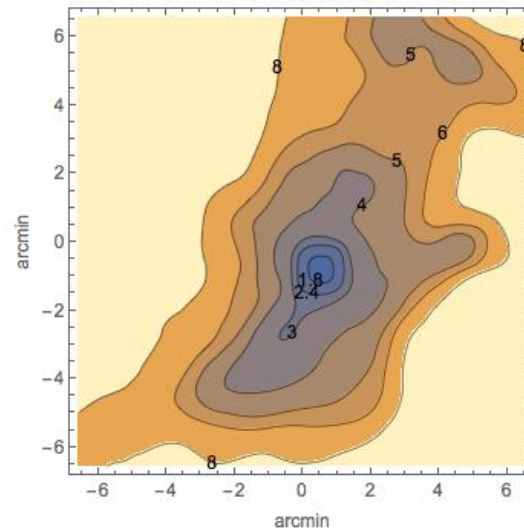
MSH 15-52

- 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

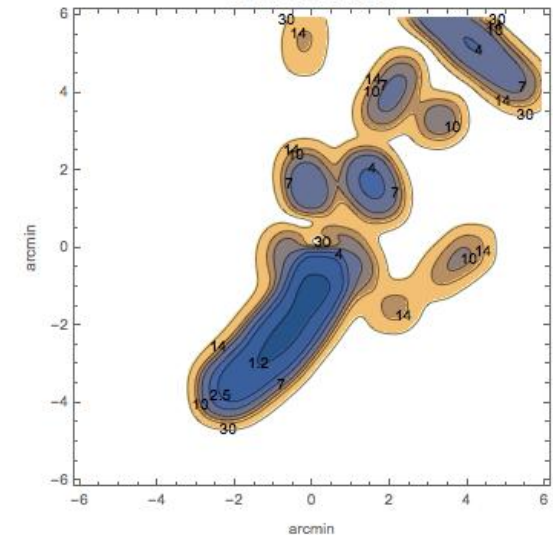
MSH 15-52 Simulated at IXPE Resolution
Segments oriented at P.A.; Length \propto P.D.



1- σ Error in Degree of Polarization (%)
for 60" \times 60" bin size

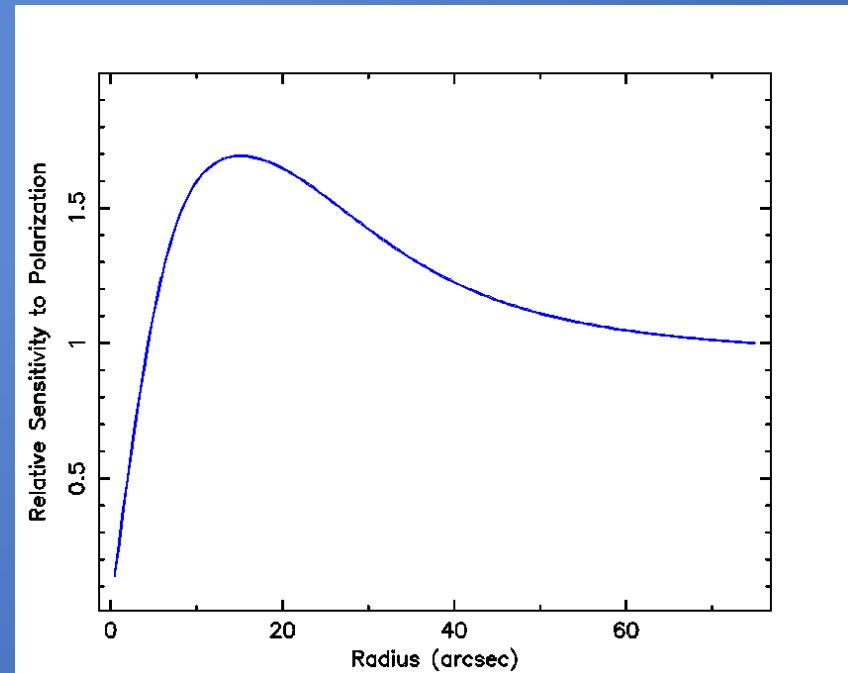


1- σ Error in Position Angle (°)
for 60" \times 60" bin size



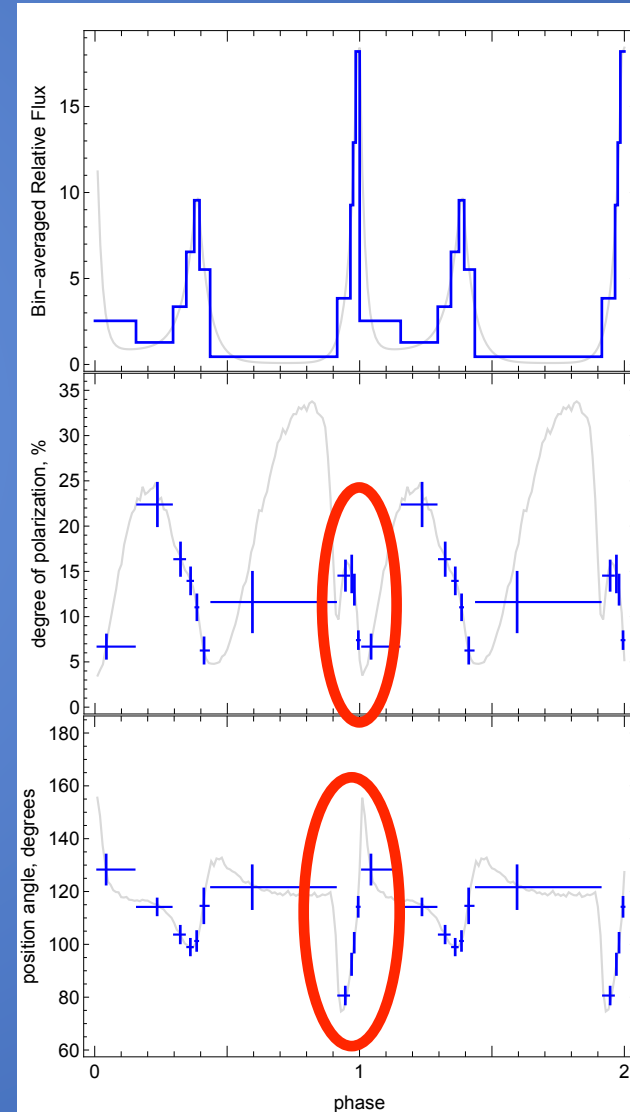
Radio pulsars

- 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



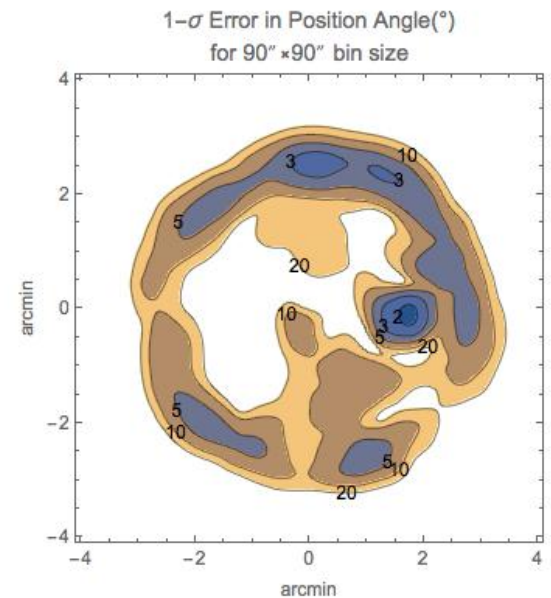
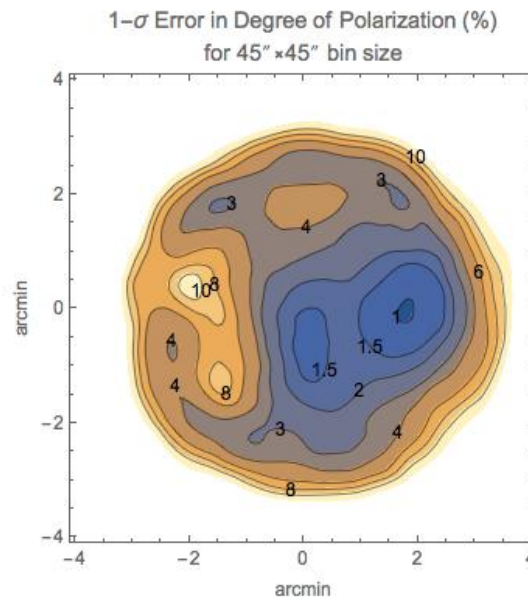
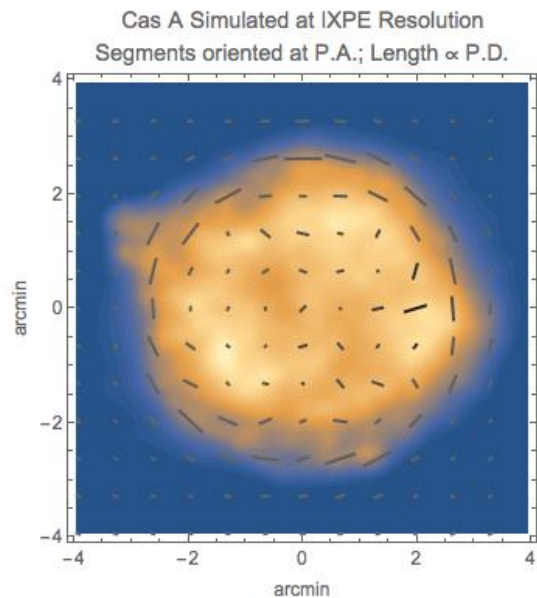
Phase-dependent polarimetry - Crab

- Divide pulse into 12 bins of \sim 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



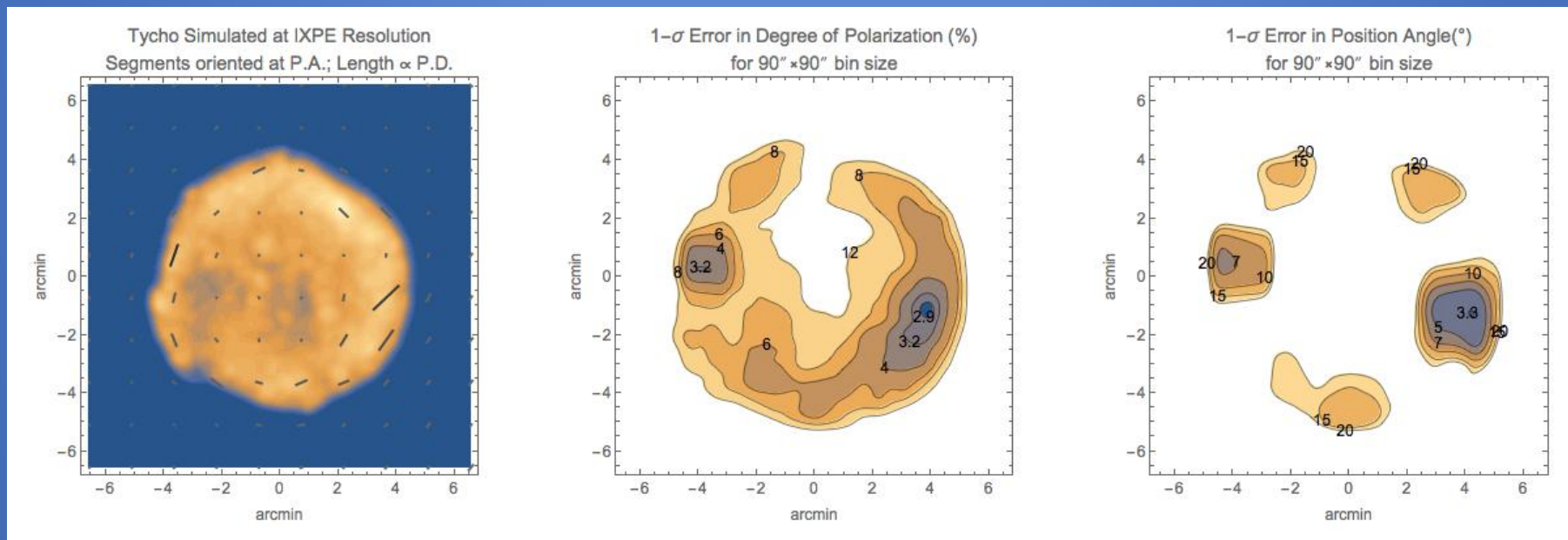
Supernova remnants – Cas A

- 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



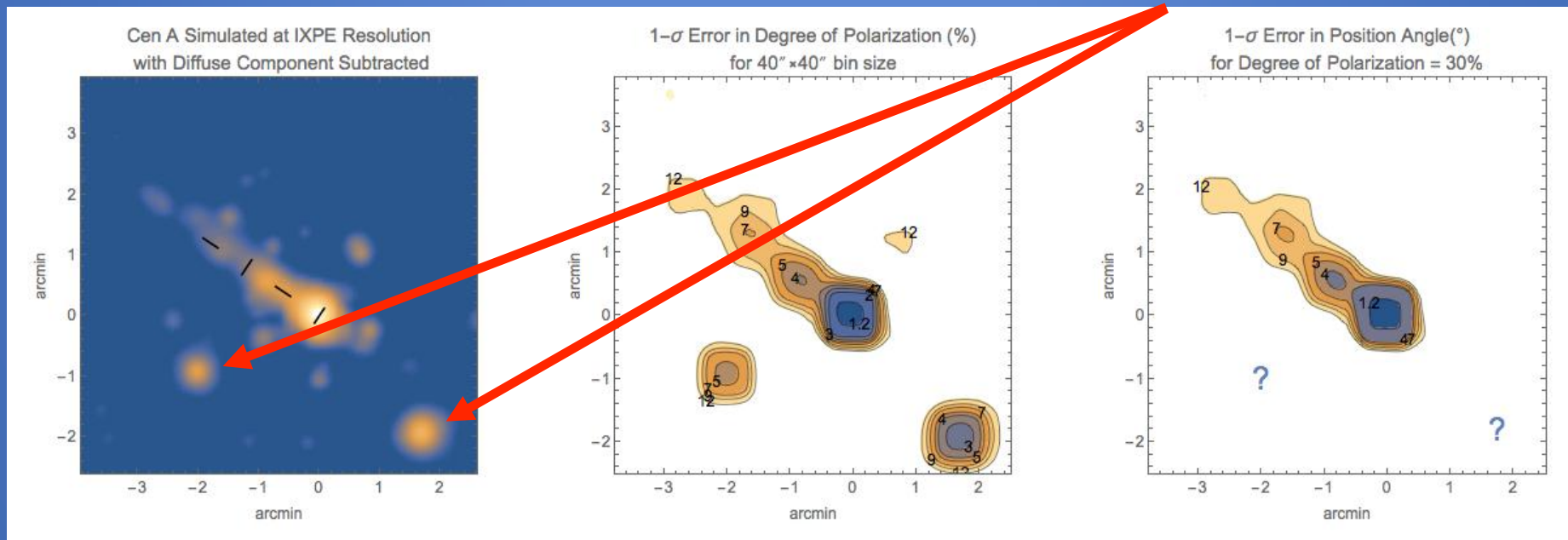
Supernova remnants - Tycho

- 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



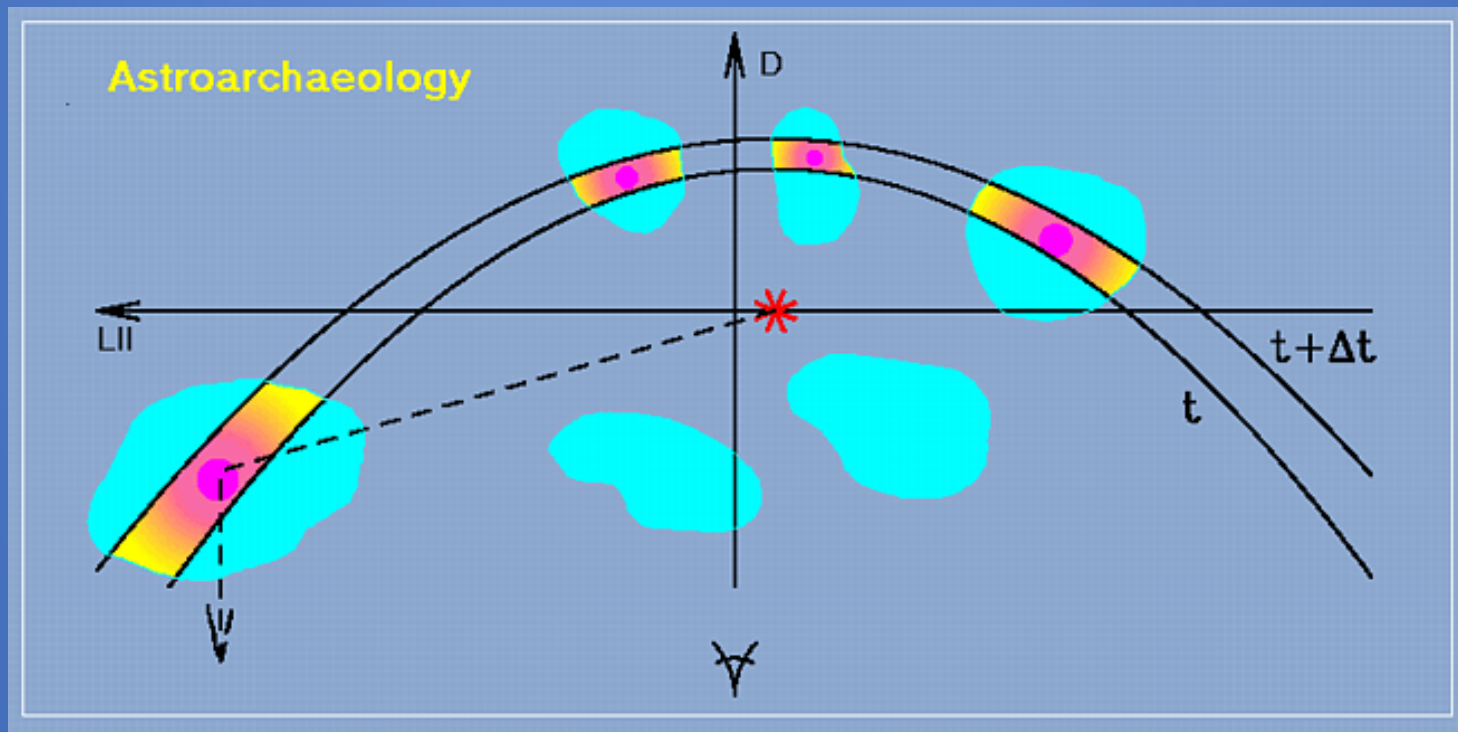
Active galaxies and their jets – Cen A

- 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



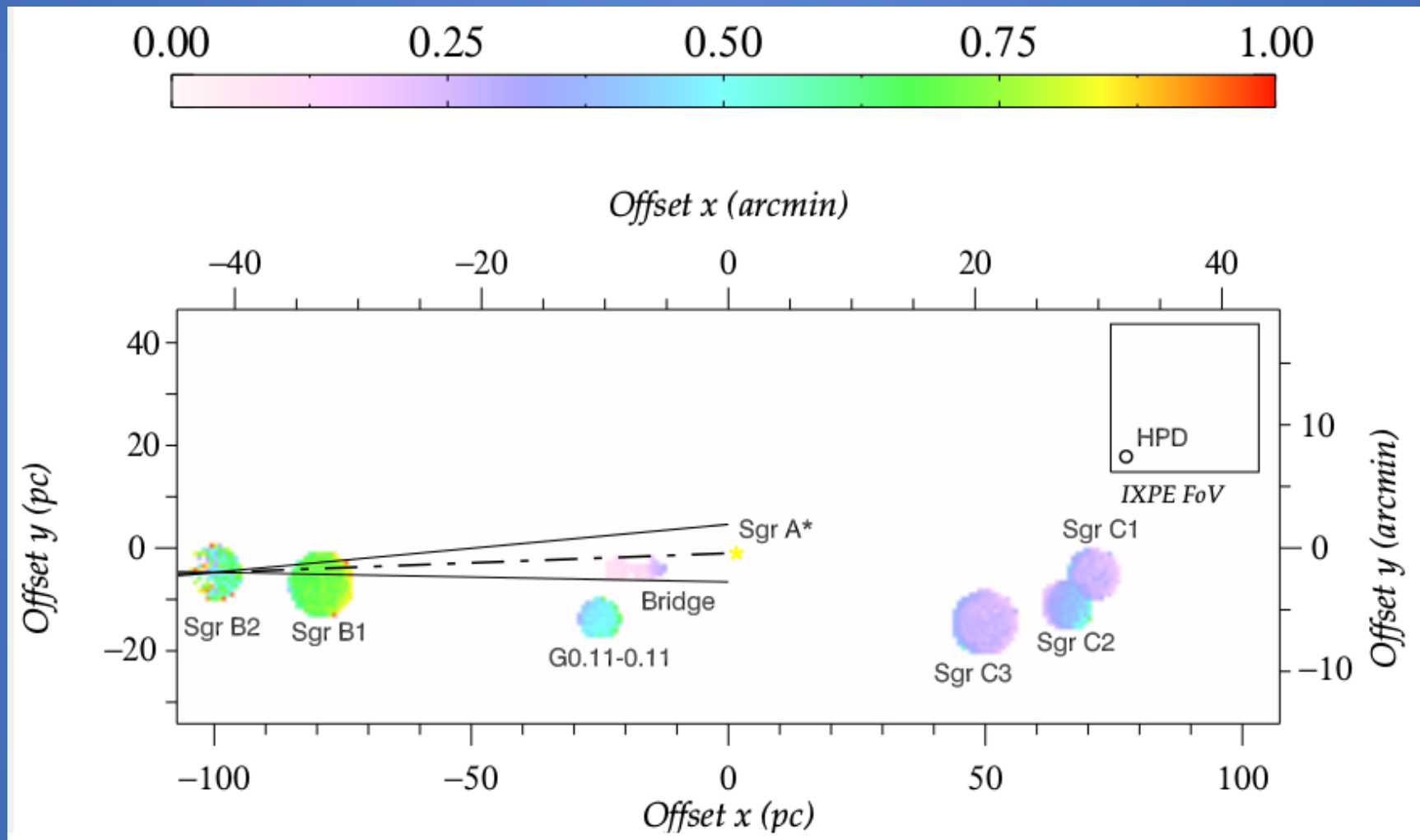
Probing the Galactic Center

- 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-8¹⁴

- 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

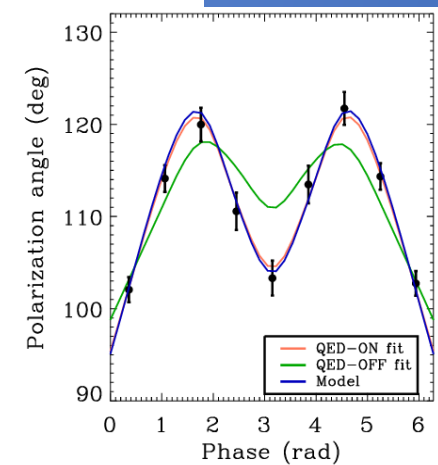
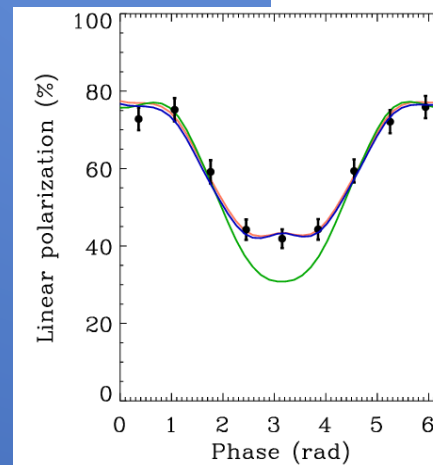
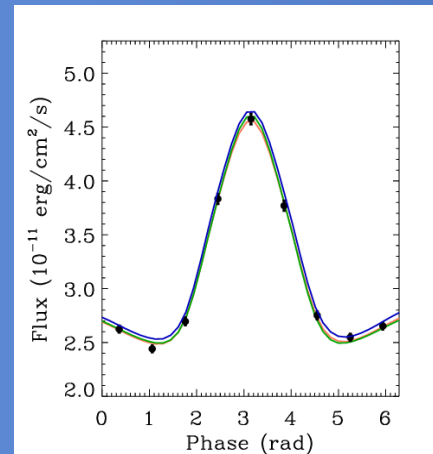
LMXB/AMSP

MICRO-QSO BH BINARY

GALACTIC CENTER

AGN

ULX

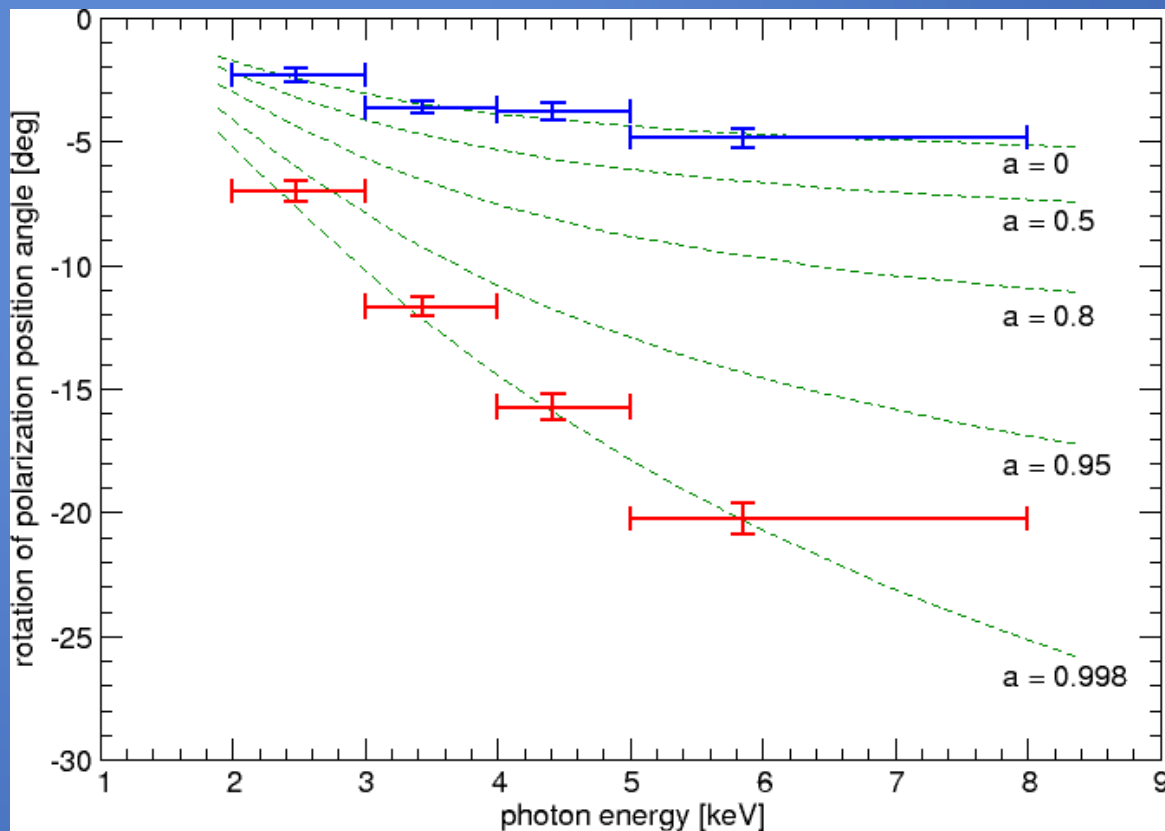


Expansion of Measurements over OSO-8¹⁵

- 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

