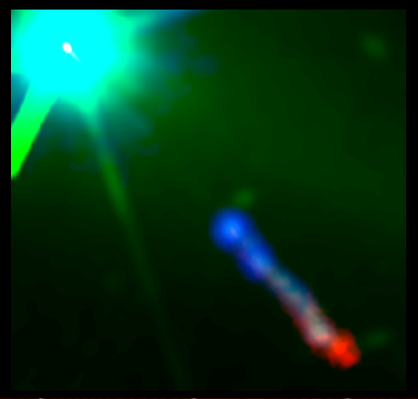
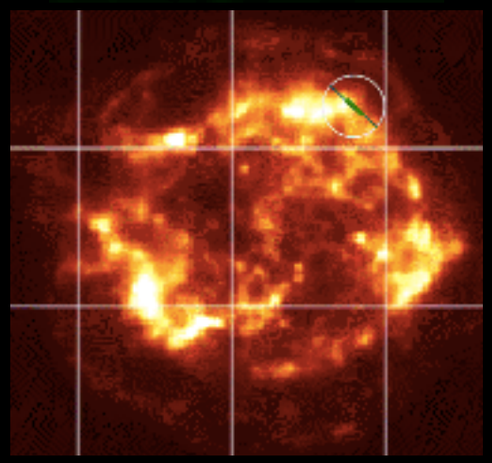
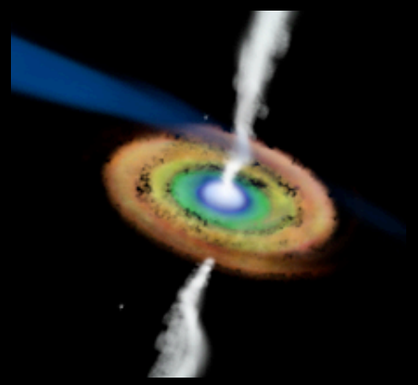




IXPE

Imaging X-Ray Polarimetry Explorer

Herman L. Marshall (MIT)
for the IXPE team



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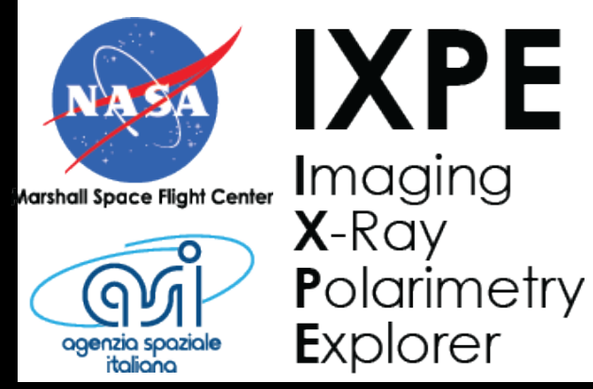
Mission Overview



- Imaging x-ray polarimetry in 2–8 keV band
- Falcon 9 launch to low Earth orbit in May 2021
- Small Explorer Design
  - X-ray (polarization-sensitive) detectors by IAPS/INAF and INFN
  - X-ray Mirror Module Assemblies by NASA/MSFC
  - Spacecraft by Ball Aerospace, payload boom from Orbital-ATK
  - SOC at MSFC, communications via LASP and ASI/Malindi
- Scientific Targets
  - Magnetars and isolated pulsars
  - Supernova remnants and pulsar wind nebulae
  - Microquasars, accreting x-ray pulsars, and transients
  - Active galactic nuclei

The Imaging X-ray Polarimetry Explorer (IXPE)

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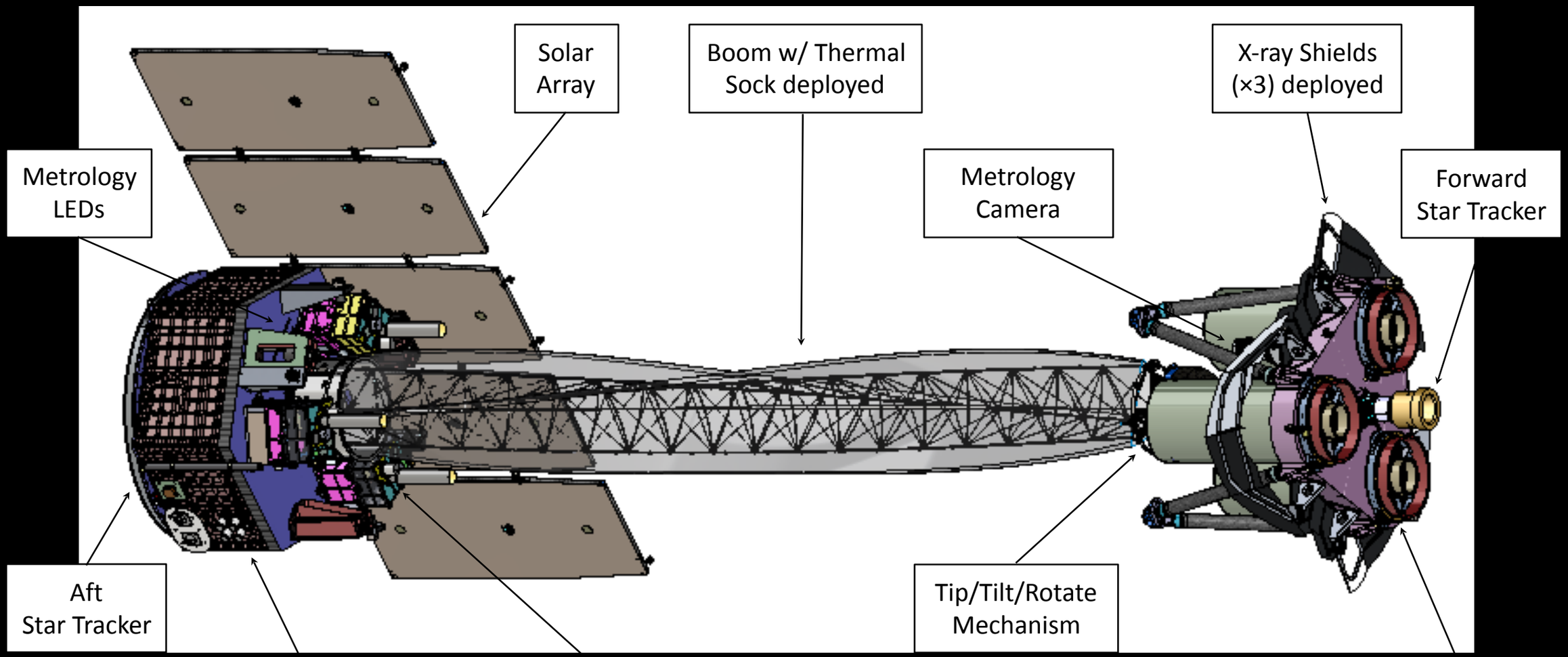
IXPE
Imaging
X-Ray
Polarimetry
Explorer



Who is involved?

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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

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Polarization-sensitive imaging detector systems

LASP Mission operations

Scientific theory

Co-Investigator

Co-Investigator

Science Advisory Team

Principal Investigator: Martin C. Weisskopf (MSFC)

Co-Investigators: Luca Baldini, Ronaldo Bellazzini, Enrico Costa, Ronald Elsner, Victoria Kaspi, Jeffery Kolodziejczak, Luca Latronico, Herman Marshall, Giorgio Matt, Fabio Muleri, Stephen L. O'Dell, Brian D. Ramsey, Roger W. Romani, Paolo Soffitta, Allyn Tennant

Mirror Module Assembly (MMA)

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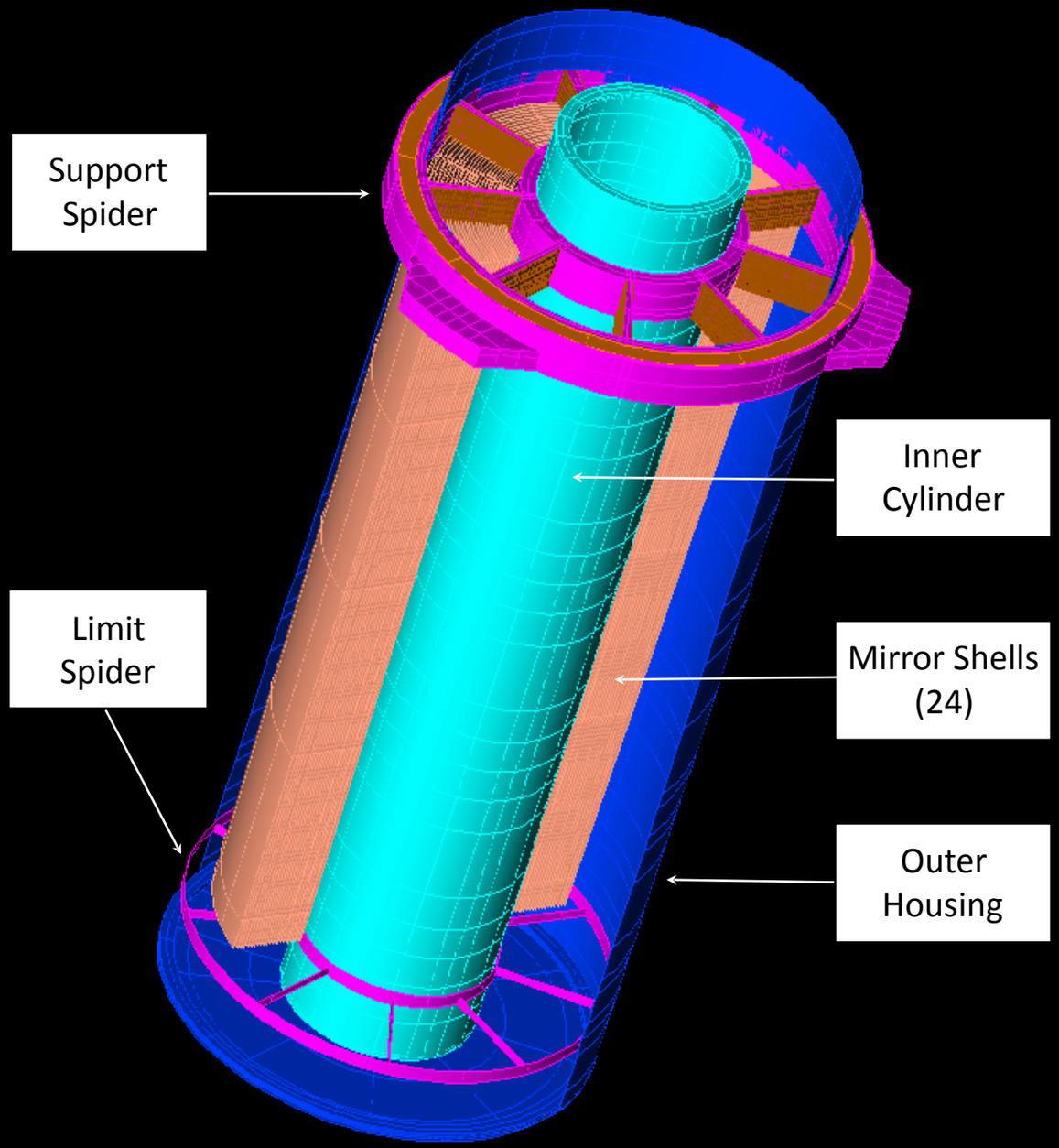

Property	Value
Number of MMAs	3
Mirror shells per MMA	24
Focal length	4000 mm
Shell length (P+S combined)	600 mm
Inner–outer shell diameter	162–272 mm
Inner–outer shell thickness	0.18–0.26 mm
Shell material	Nickel–Cobalt alloy
Mass per MMA	30 kg
Effective area per MMA	210 cm^2 (2.3 keV) > 230 cm^2 (3–6 keV)
Angular resolution	≤ 25 arcsec HPD
Field of view (detector-limited)	12.9 arcmin

Imaging Polarimetry Detector

- Photons eject K shell electrons from detector gas atoms
- Photoelectron direction is related to the photon's polarization angle
- Photoelectron loses energy via L shell ionizations; total charge is proportional to E
- Charge is amplified by GEM, drifts to anode

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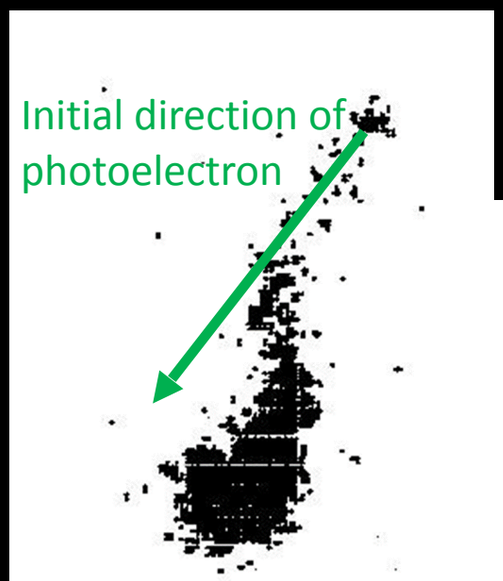
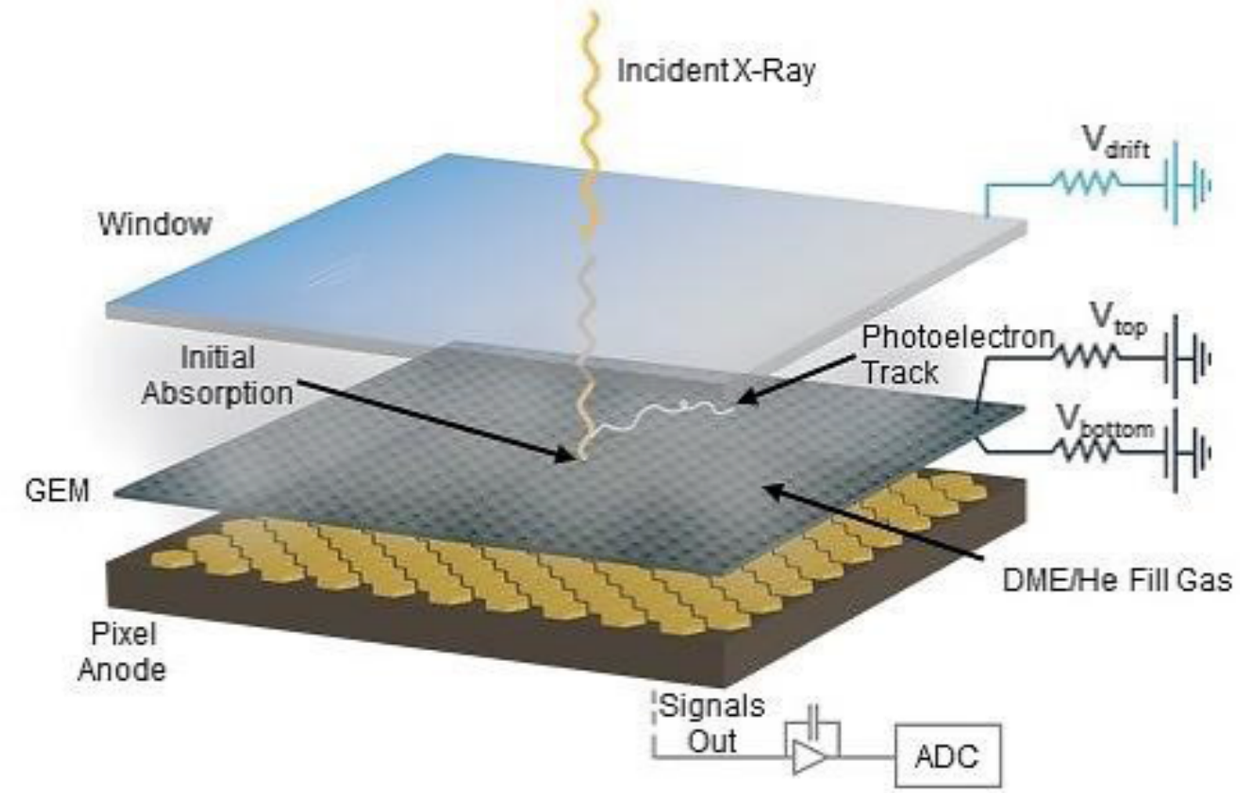
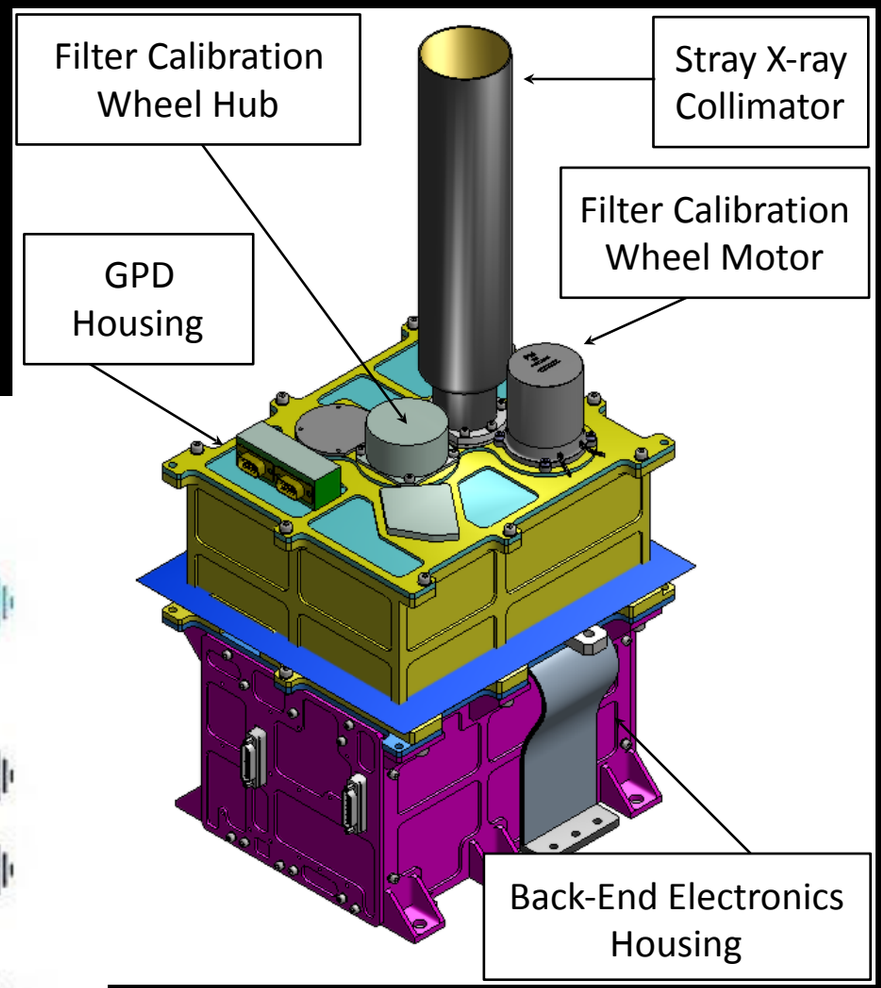


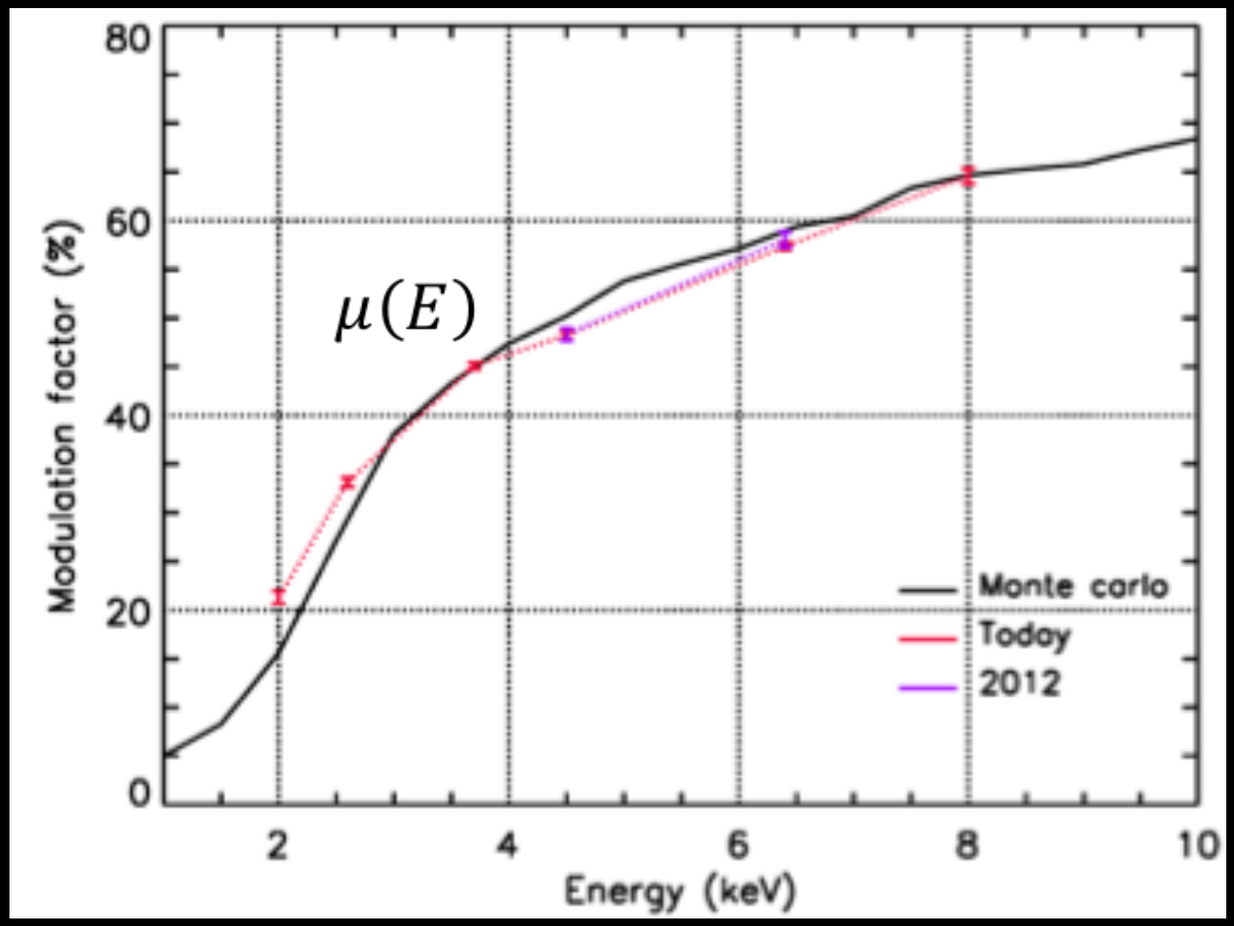


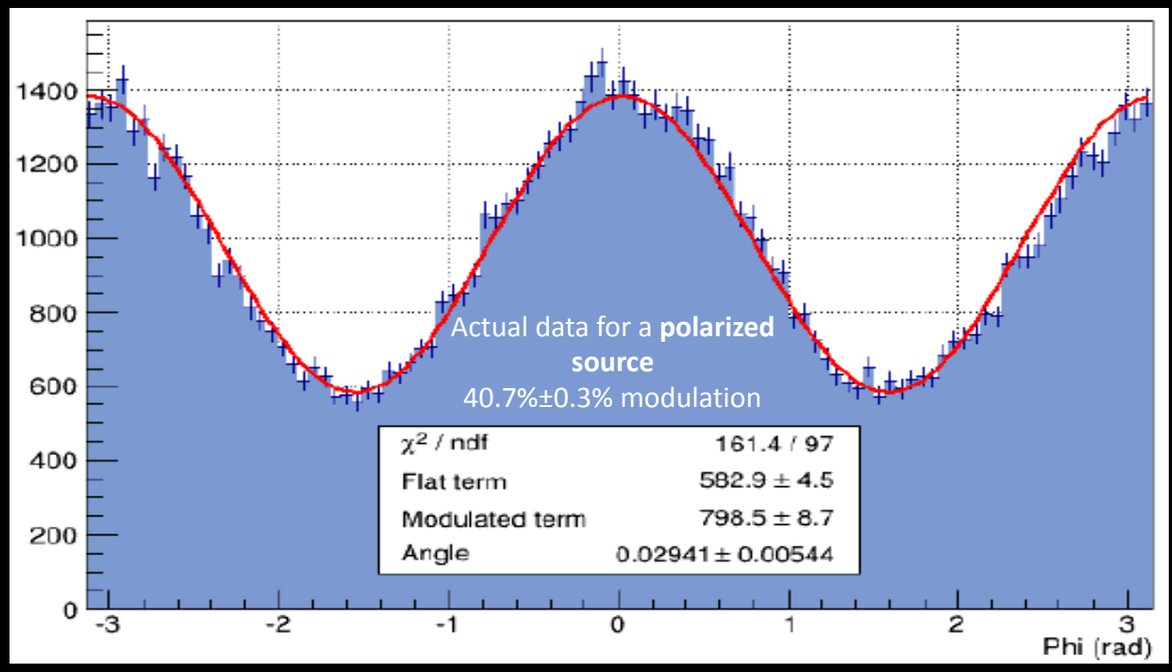
Gas Pixel Detector (GPD)

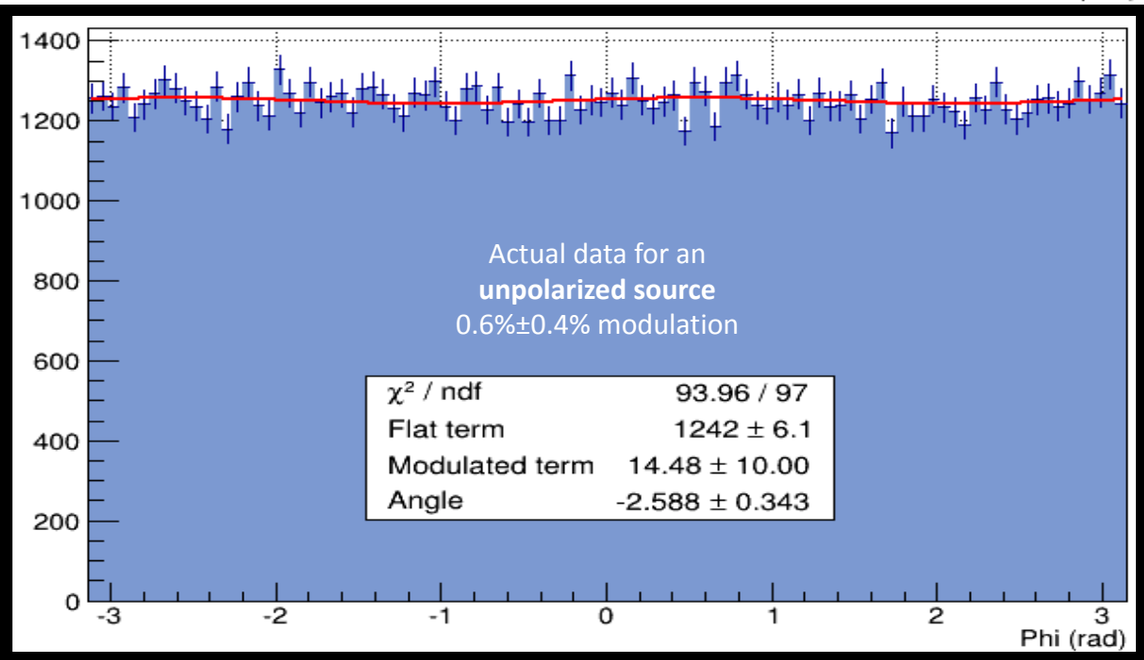


Measuring Polarization

- Modulation factor: response to 100% polarized X-rays
- Tracks are longer, easier to measure at high energy







IXPE Topical Working Groups

Involve the scientific community to set the observing plan

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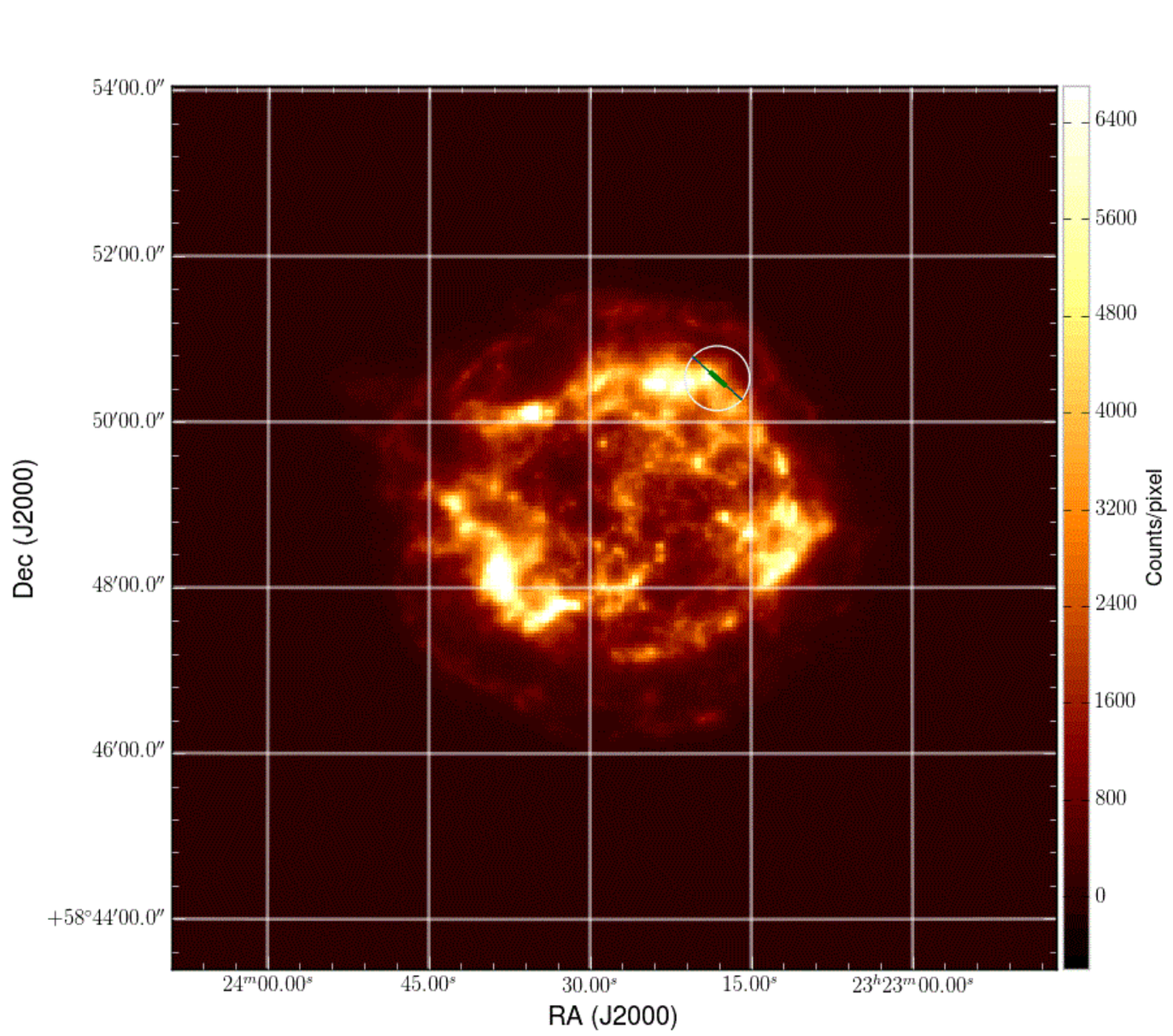
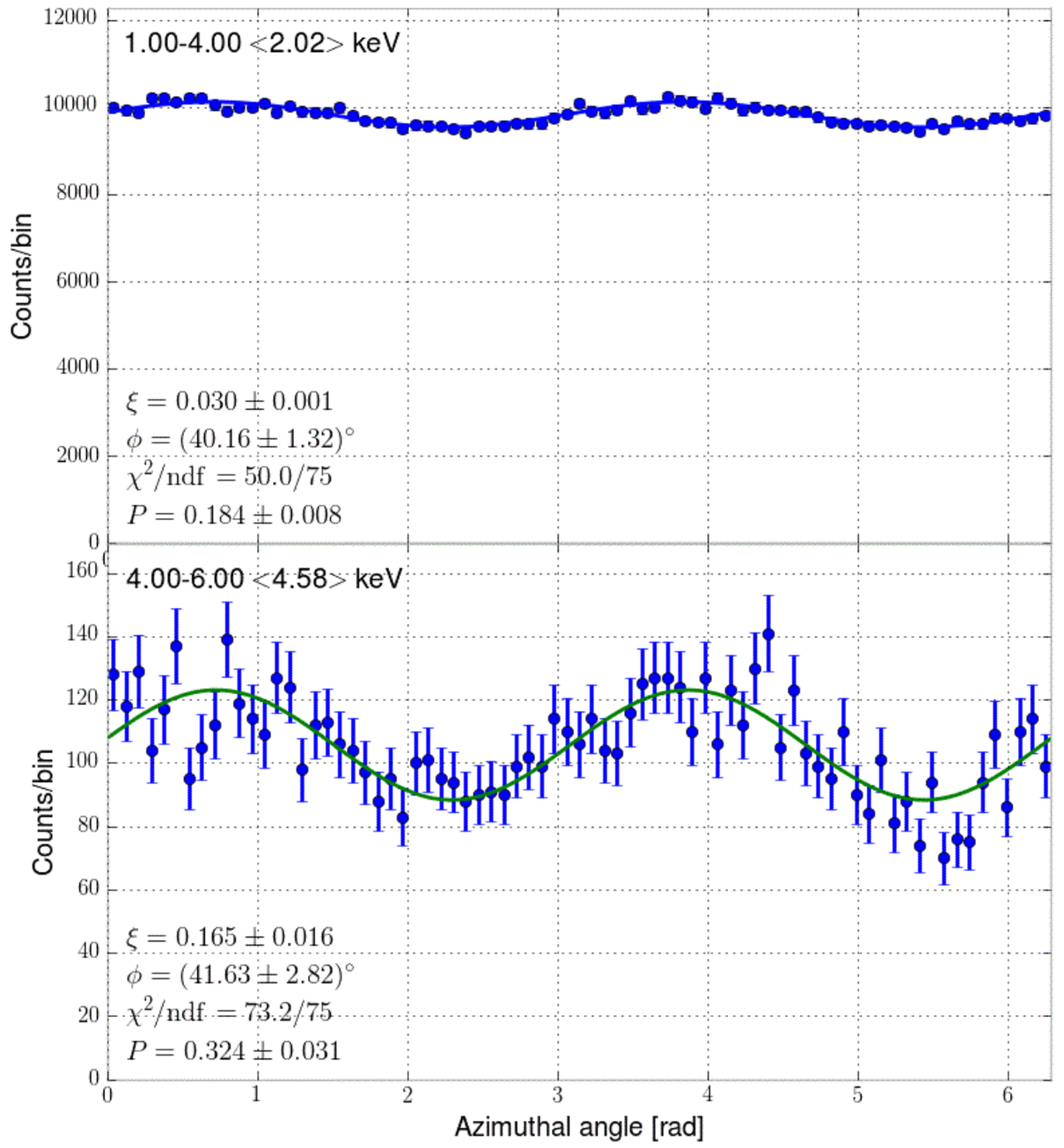
1. Isolated Pulsars & Pulsar Wind Nebulae (e.g., Crab, Vela)
2. Supernova Remnants (e.g. Cas A, Tycho)
3. Accreting Stellar-mass Black Holes (e.g. Cyg X-1, GRS 1915+105)
4. Accreting Neutron Stars and White Dwarfs (e.g. Her X-1, SAX J1808)
5. Magnetars —high B isolated neutron stars (e.g. 4U 0142, RX J1708)
6. Radio-quiet AGN, Galaxies (e.g. NGC 4151, Sgr A*)
7. Radio-loud AGN and Blazars (e.g. Mk 421, Cen A)

Cassiopeia A
Supernova Remnant
(About 300 yr old at 3.4 kpc)





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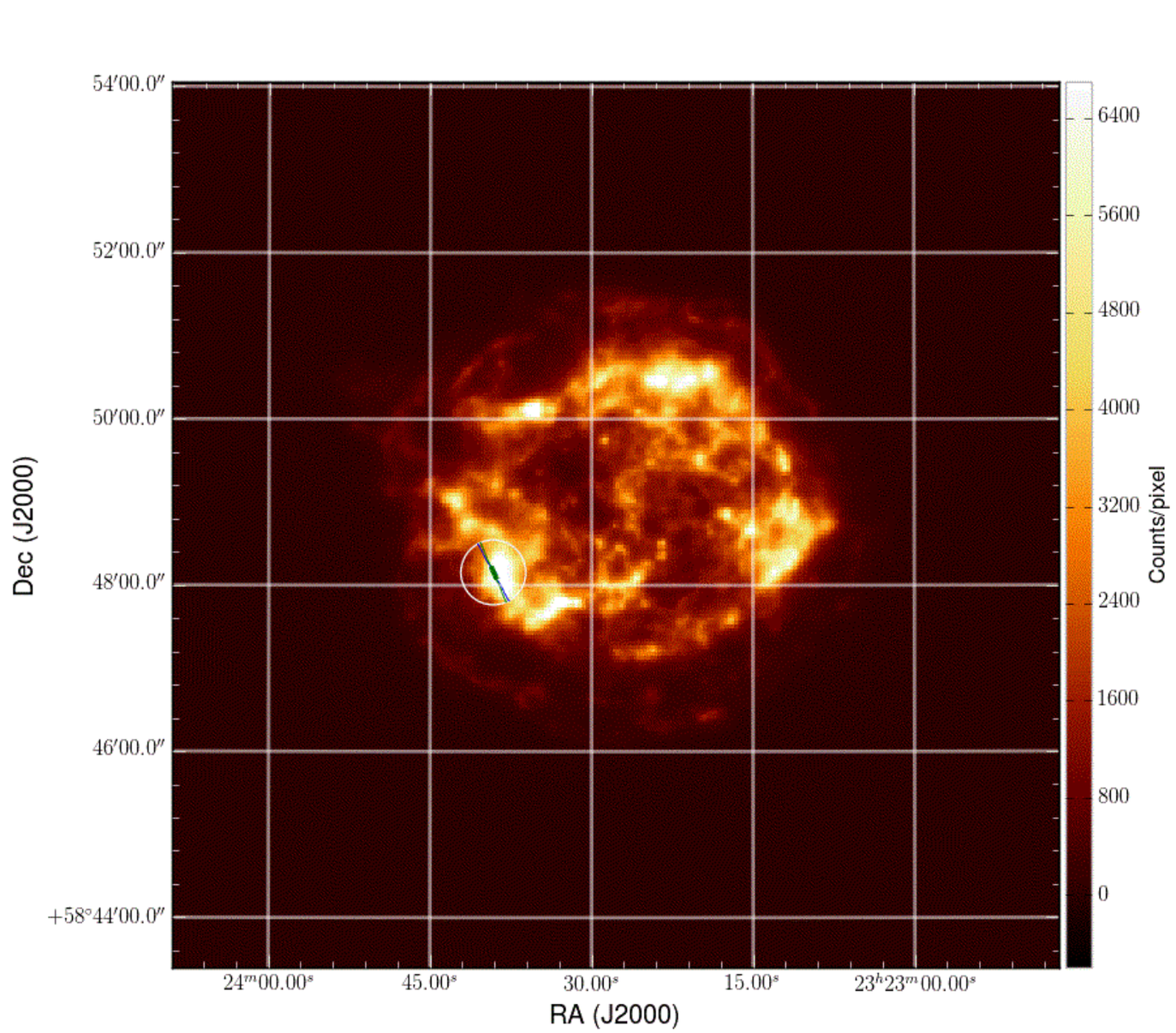

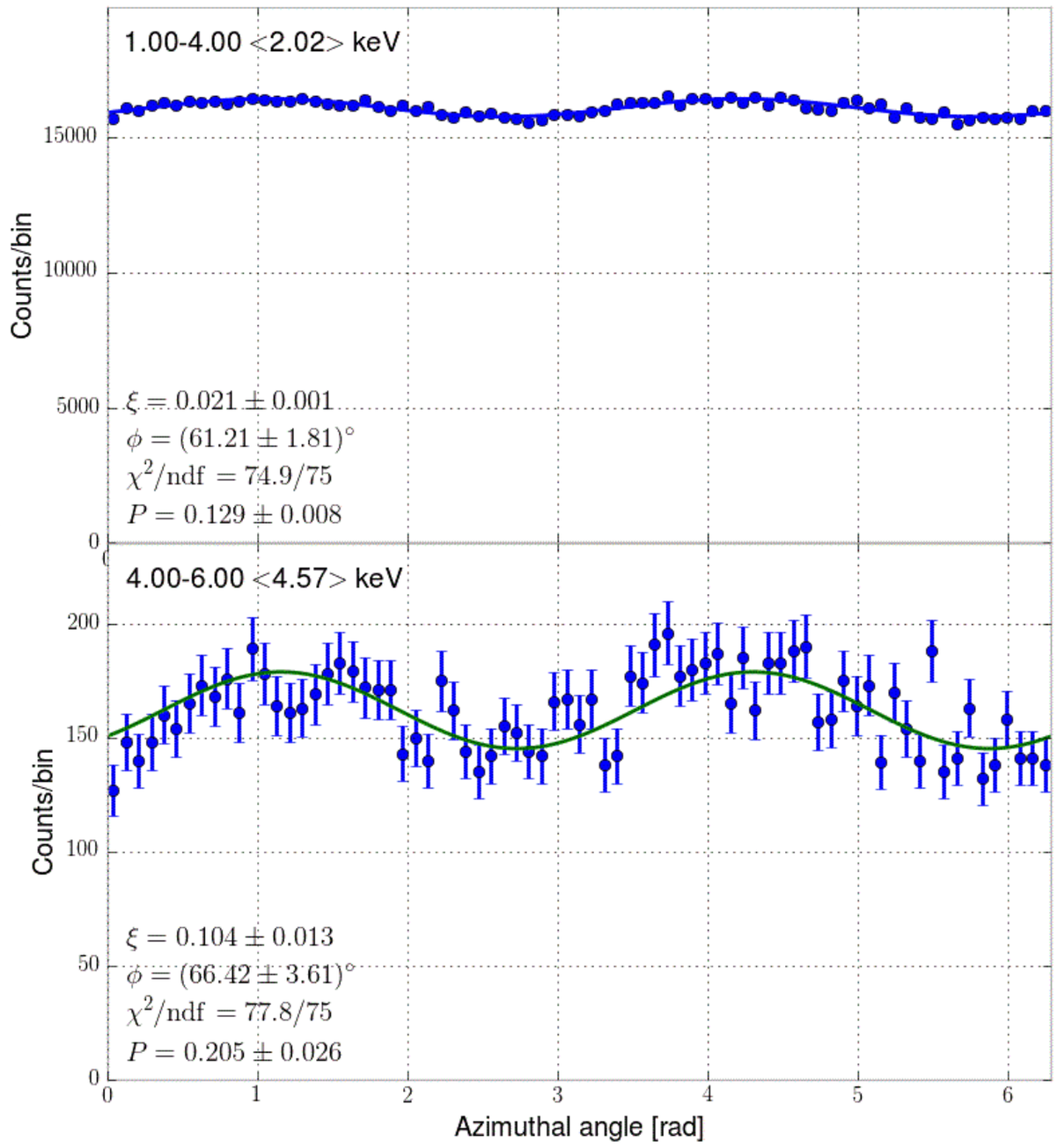

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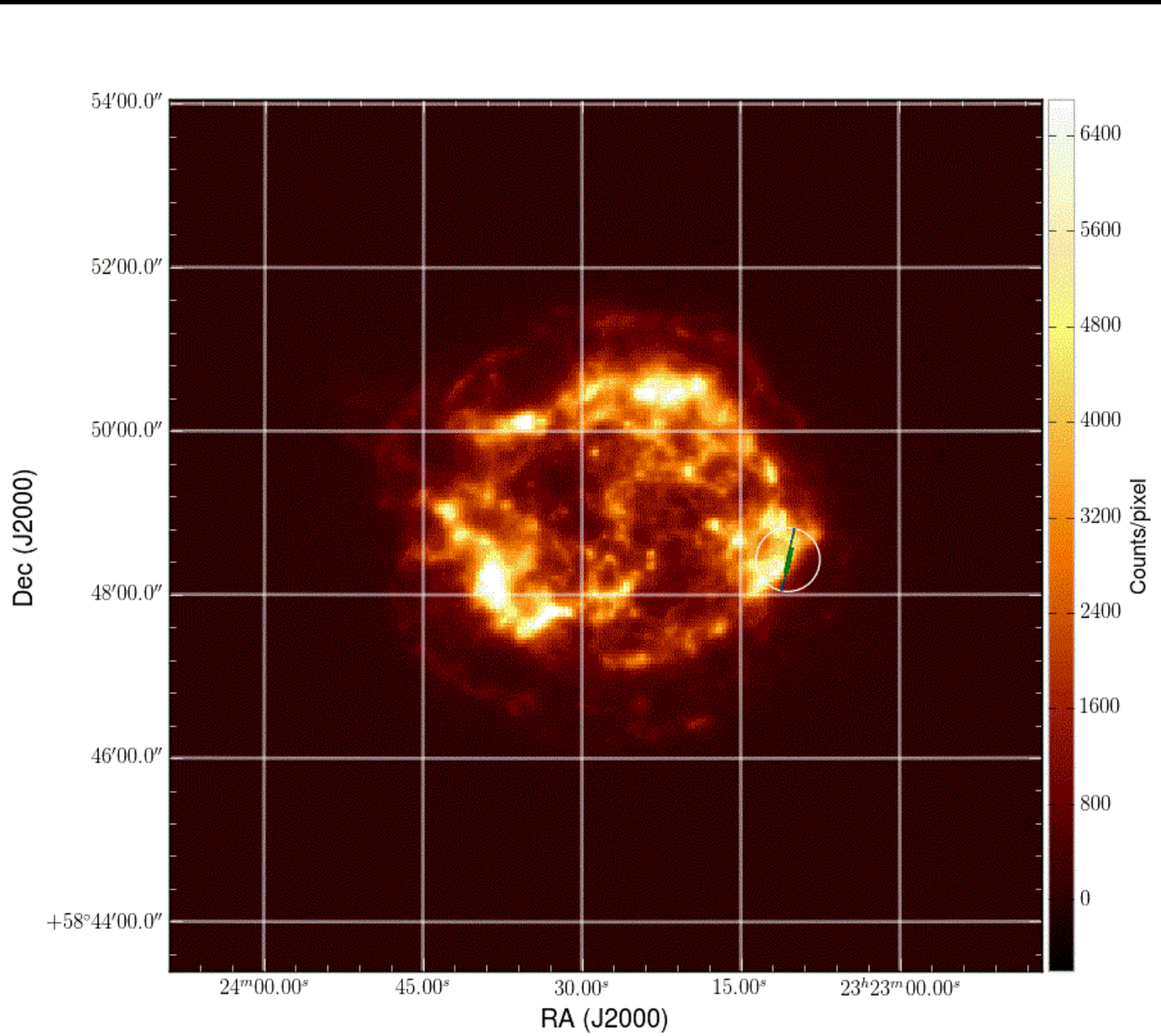

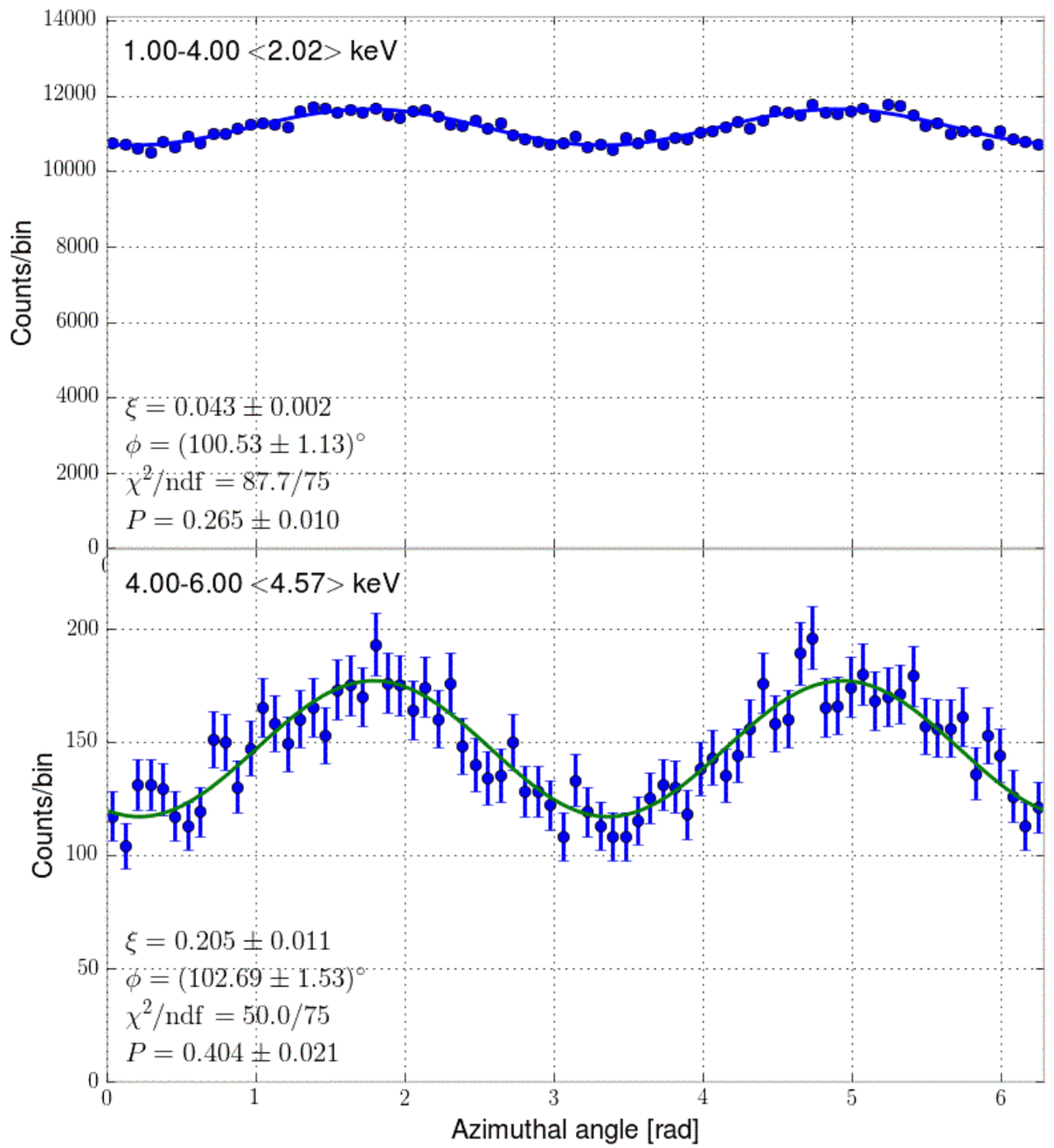

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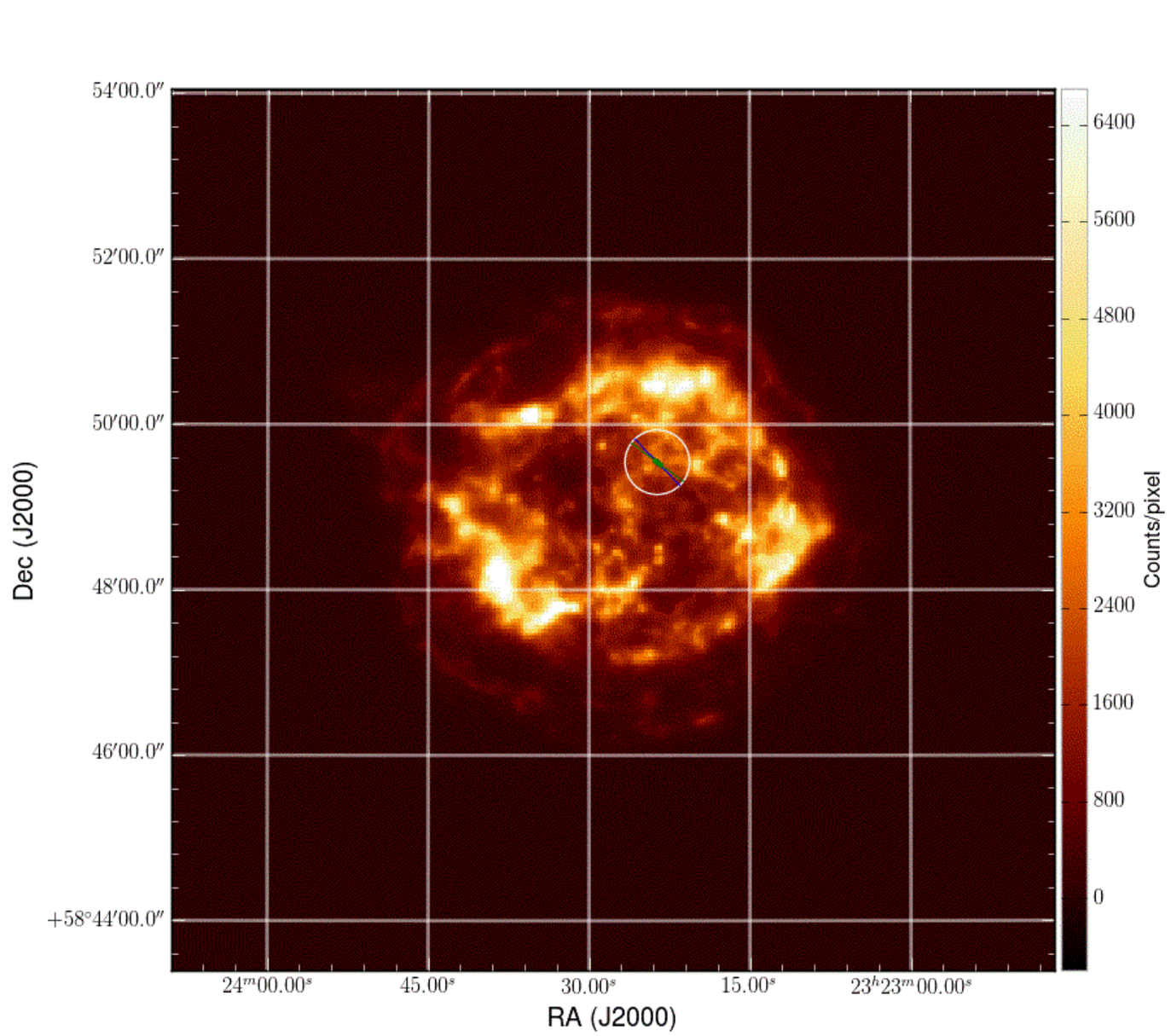

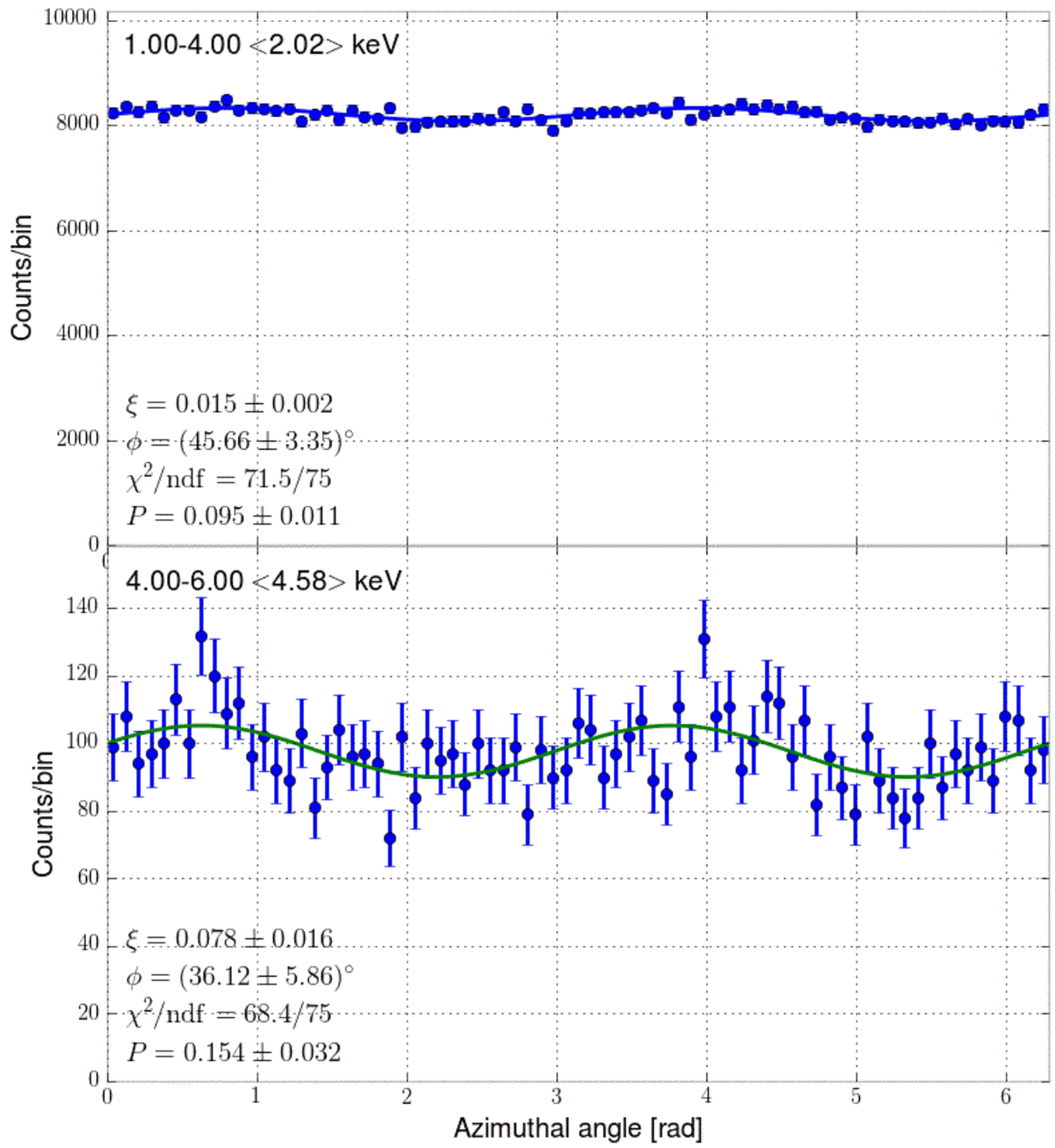

Black-hole spin from polarization rotation in twisted space-time

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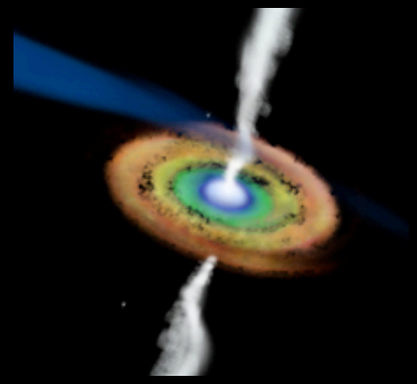
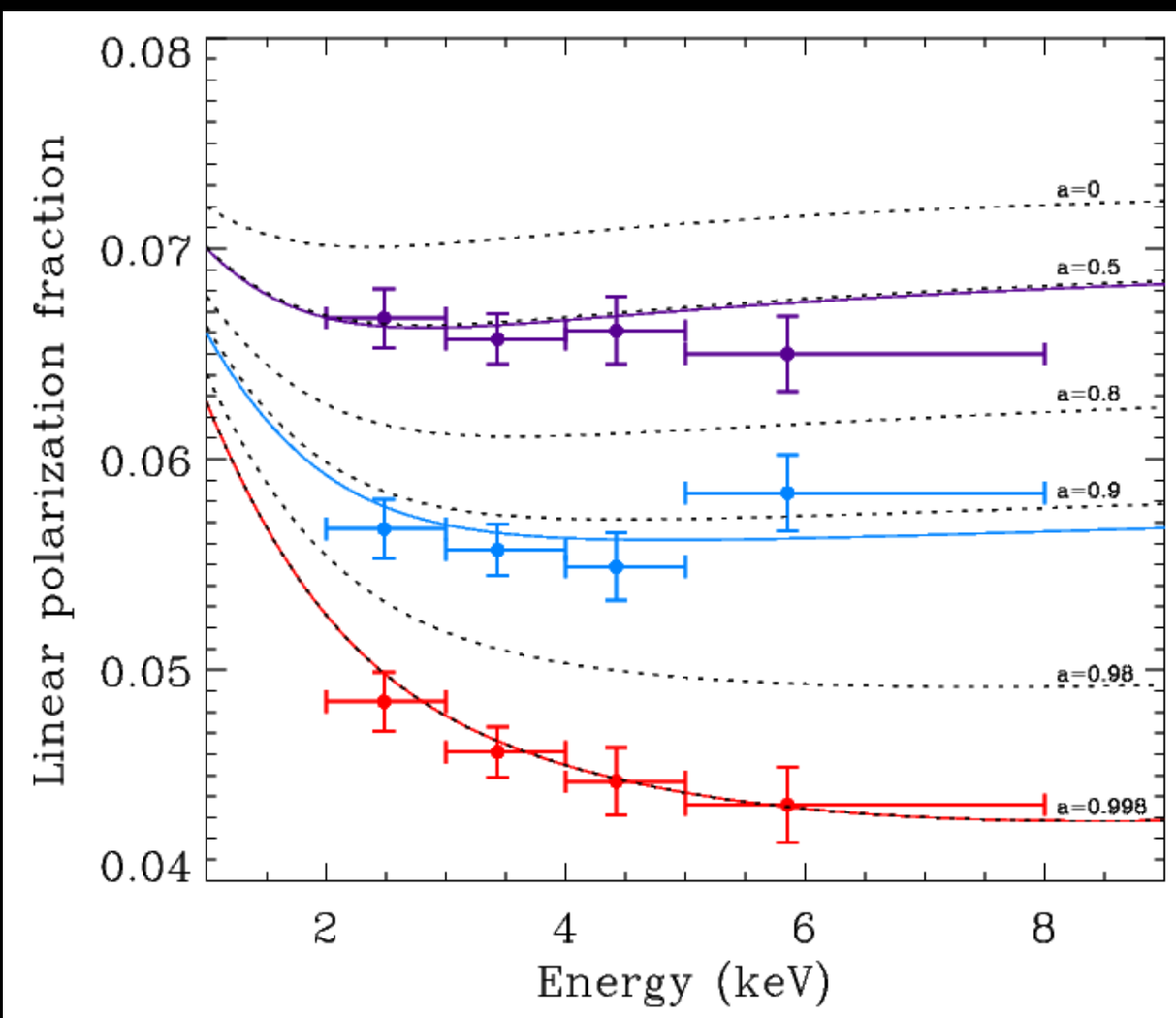
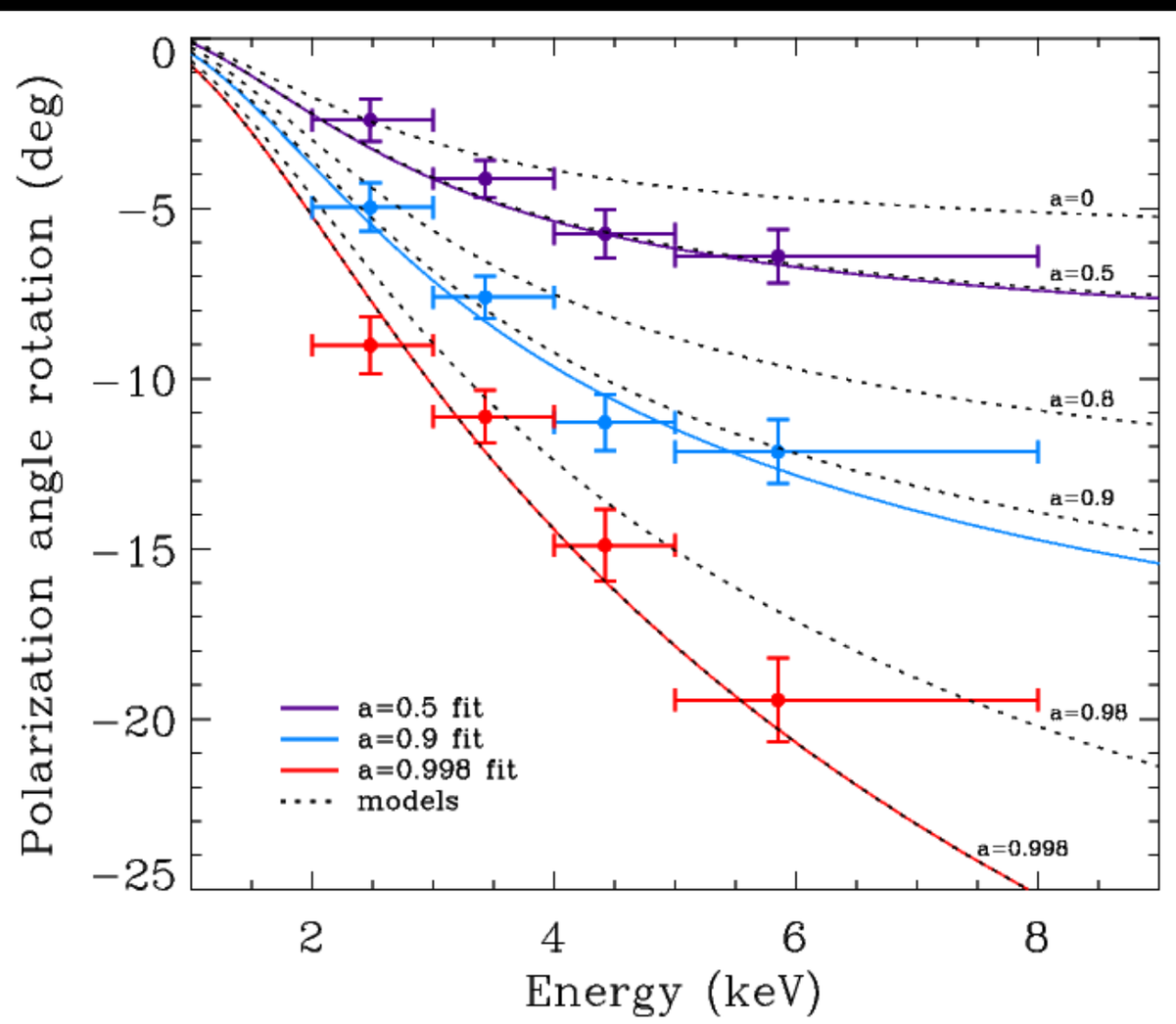


- Example: accretion-dominated microquasar (GRS 1915+105)
- 200-ks simulated observation
- Can use prior disk-orientation information from radio jet





Phase-resolved polarimetry of X-ray pulsars

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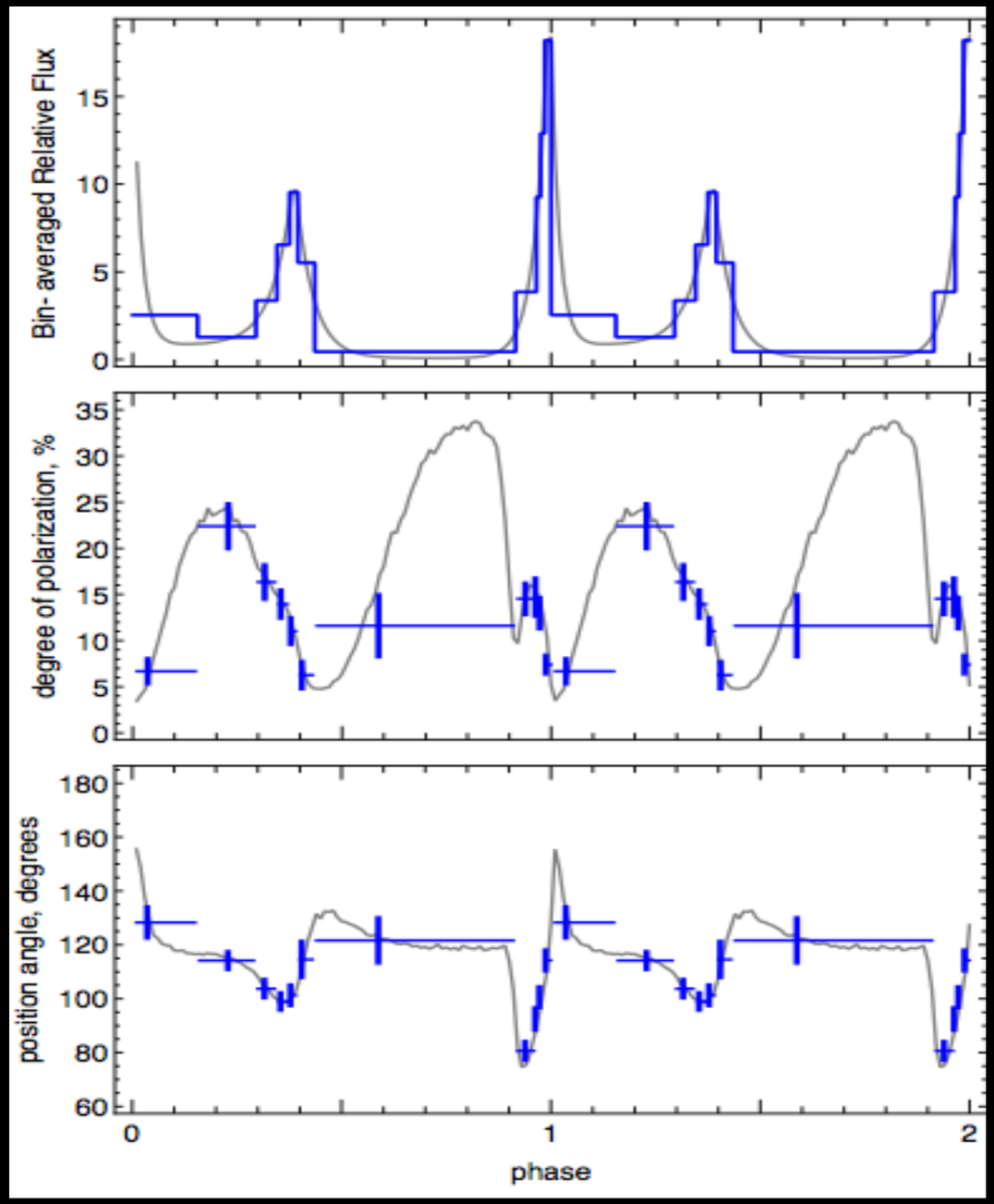
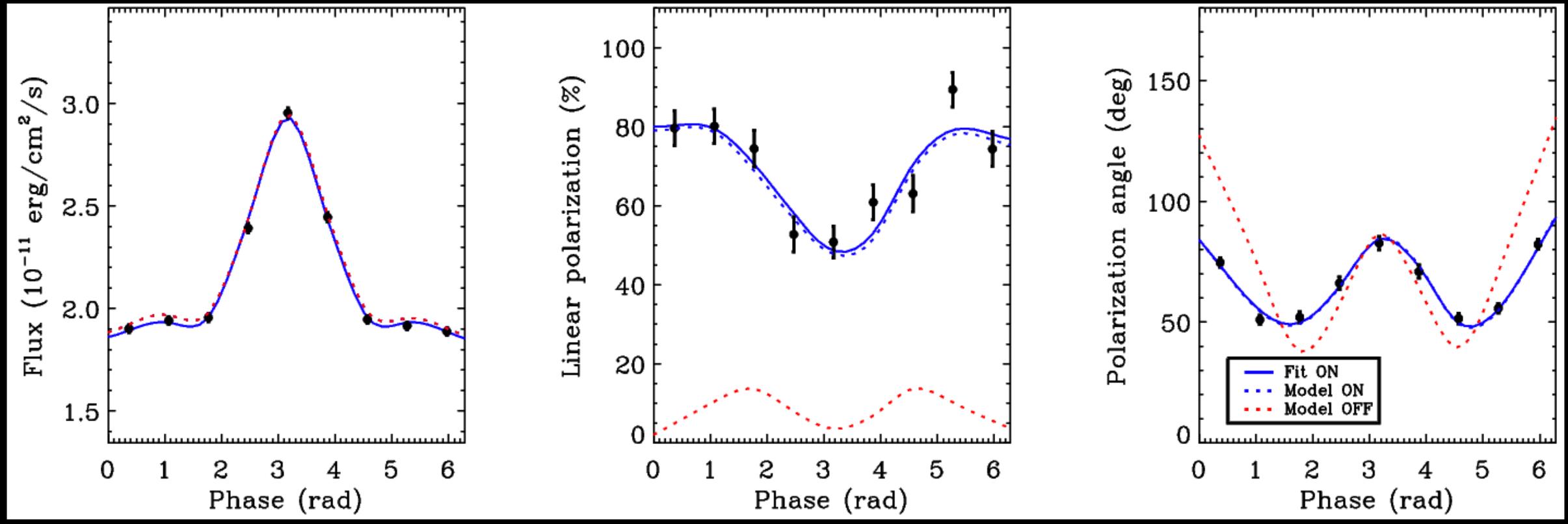
- Isolated pulsars
  - Example: Crab pulsar
    - In pulsar wind nebula (PWNe)
    - 34-ms pulse period
    - 140-ks IXPE (simulated) observation [blue]
      - Based upon visible-band polarization profiles [grey]
- Accreting x-ray pulsars
  - Classical (high-B) binaries
  - Millisecond (low-B) binaries



Testing Quantum Electrodynamics with Magnetars

- Magnetars: slowly rotating neutron stars with $B > 10^{14}$ G
- Magnetized vacuum is birefringent
- Flux is unaffected but polarization fraction and angle change with spin phase



Centaurus A: The Nearest Active Galaxy

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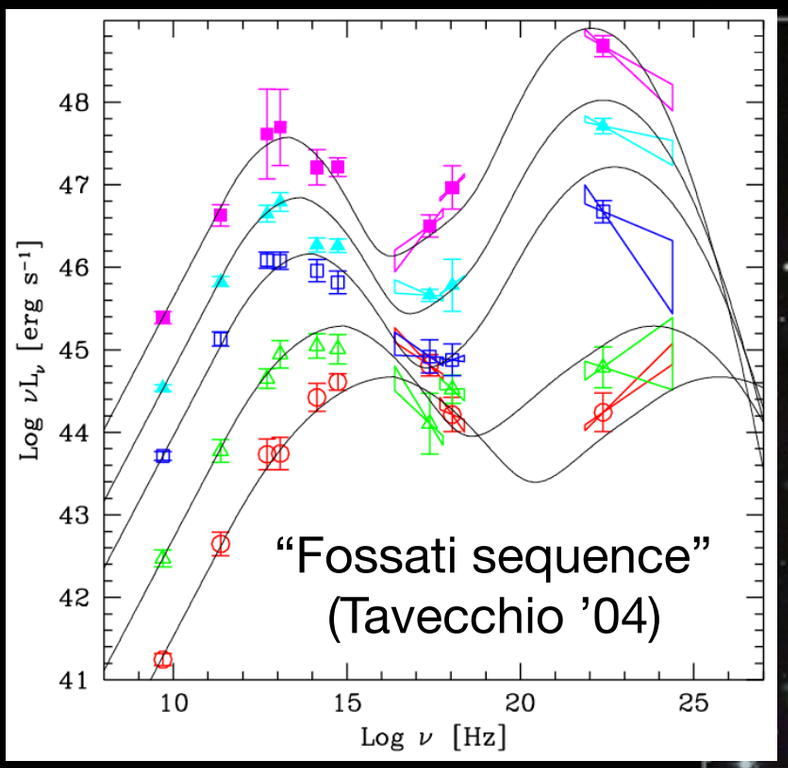
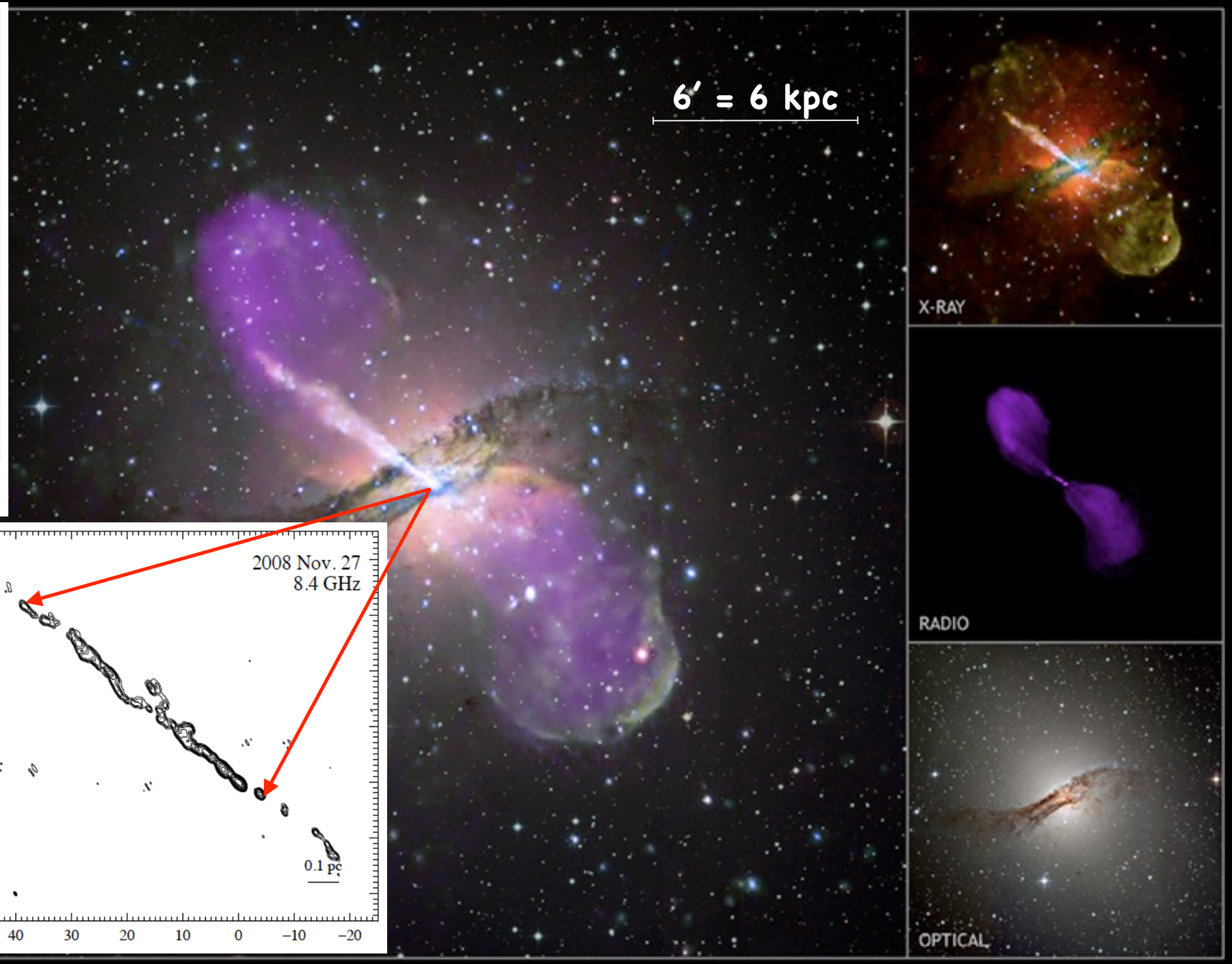


"Fossati sequence"
(Tavecchio '04)



IXPE will image jet knots and find serendipitous sources

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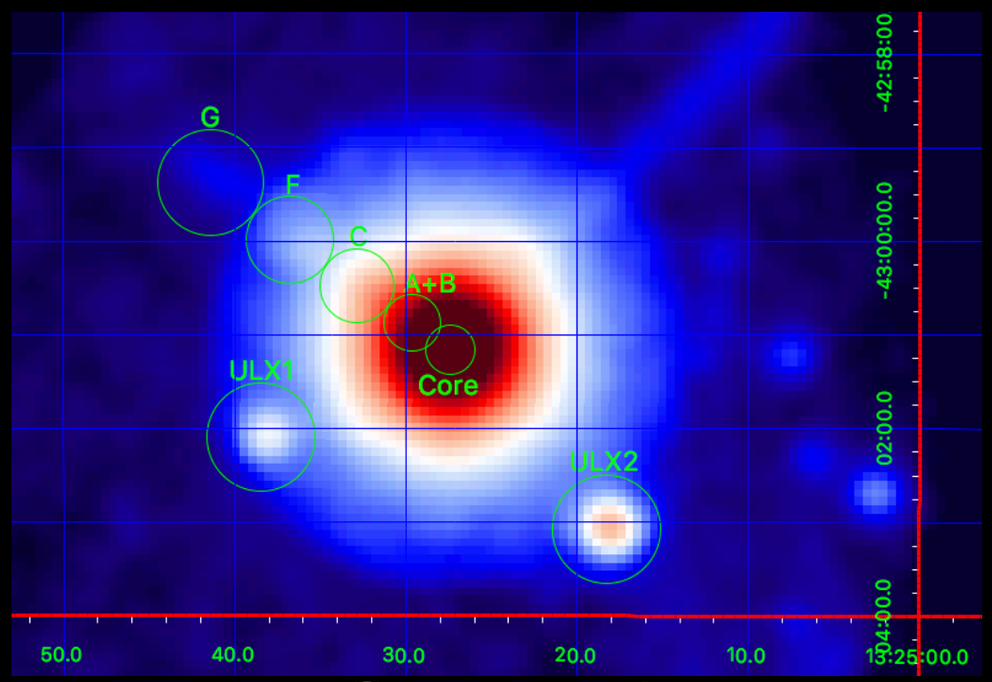
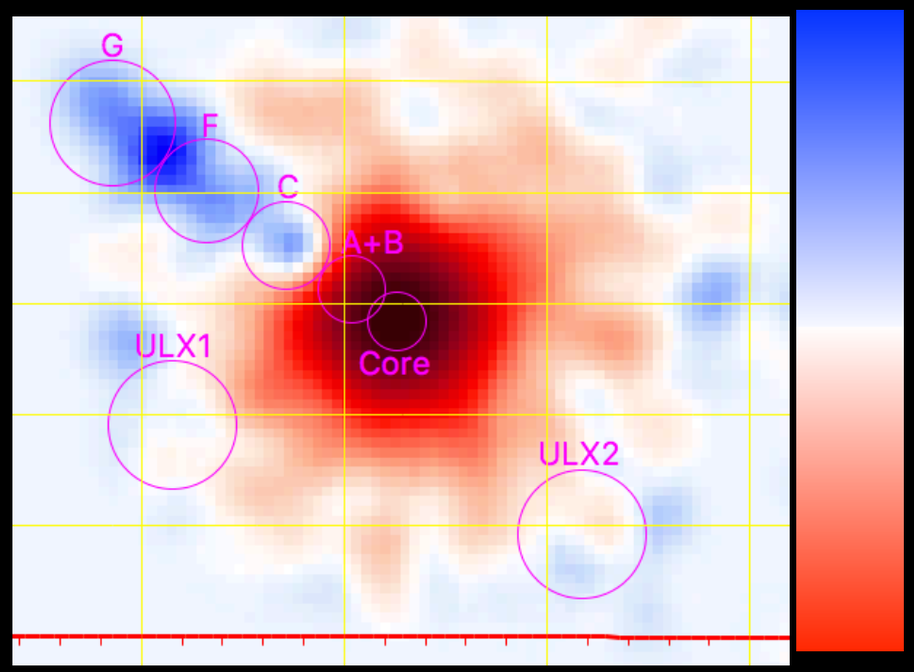
- **Radio loud active galaxies, powered by supermassive BHs with jets**
  - Radio polarization implies the magnetic field is aligned with jet
  - X-rays from core: self Compton, external Compton
  - Knot X-rays: jet spine or shocked regions?
  - In 200 ks, MDP = 1.3% for Cen A core, 3.5% for 3C 273 core
- **Imaging Cen A will isolate ULXs in the field**



Stokes I



Stokes Q

IXPE Status

- Detector units (Italy): Fabricated & X-ray tested
- Mirror Assemblies (MSFC): 1 done, 2 nearly complete
- Spacecraft (Ball): In assembly and test without instrument
- Telework impact
  - Detectors ship to MSFC upon return to work
  - Mirrors require 2 months assembly & testing upon return
  - Ball: some access, proceeding as feasible without detectors and optics
  - Software development on schedule
  - Schedule slipping a day per day

IXPE Summary

- Bandpass: 2-8 keV, Imaging: 25”, dE/E = 15%
- Minimum detectable polarizations to 1%
- Target examples
  - SNRs, PWNe
  - Galactic X-ray Binaries
  - Magnetars
  - AGN and Blazars
- Launch in May, 2021 + ??
- Low Earth Orbit, 2+ yr mission
- No proprietary data
- Users involved via Topical Working Groups
- No consumables; only orbit limits mission lifetime