# Scientific Prospects for Gamma-Ray Polarimetry

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Future Space-based Gamma-ray Observatories

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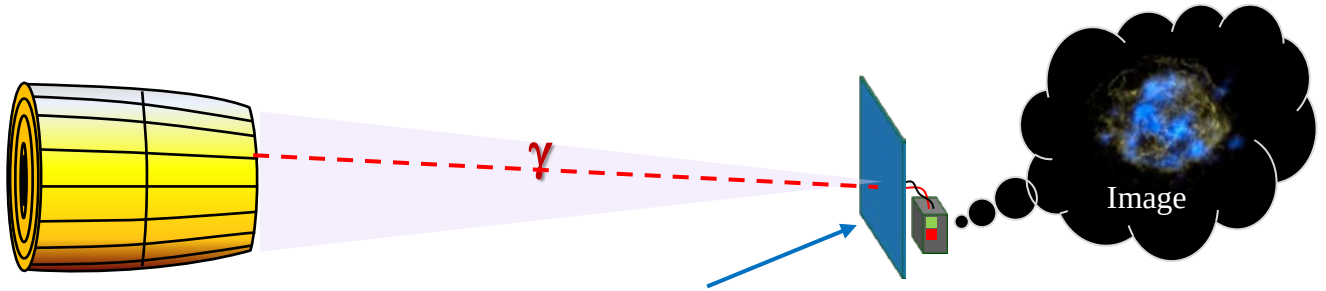
# Introduction

- Black holes
  - Emission mechanism
  - Accretion disk geometry
  - Jet structure
- Gamma-ray bursts
  - Emission mechanism
  - Magnetic structure
  - Lorentz violation
- Neutron stars, pulsars, PWN
  - Curvature and/or synchrotron radiation
  - Constrain magnetic field, particle populations, acceleration region
- **Polarimetry provides geometrical information about objects that cannot be spatially resolved**

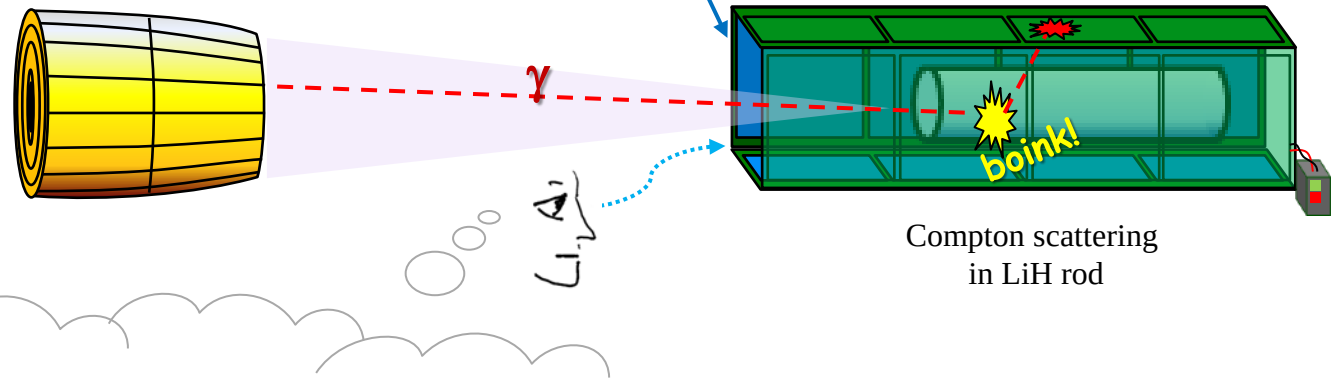
# X-ray Polarimetry with PolSTAR

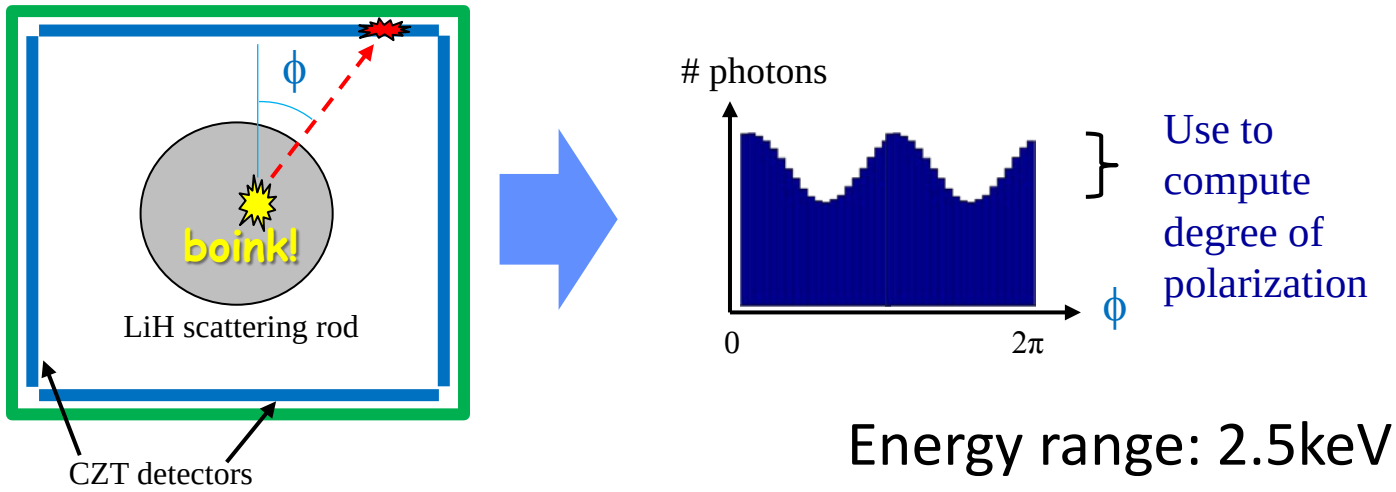
Krawczynski et al.

**NuSTAR**
(Launch: 6/2012)



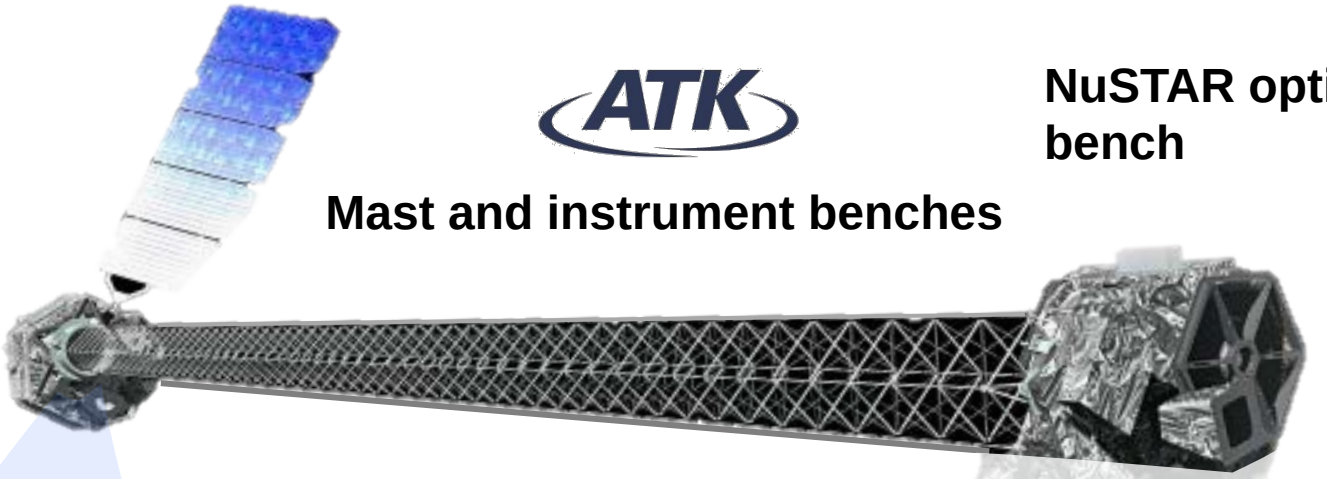

**PolSTAR**




Energy range: 2.5keV – 70keV

# From NuSTAR to PolSTAR



Orbital

**LEOSTAR-II**

ATK

**Mast and instrument benches**

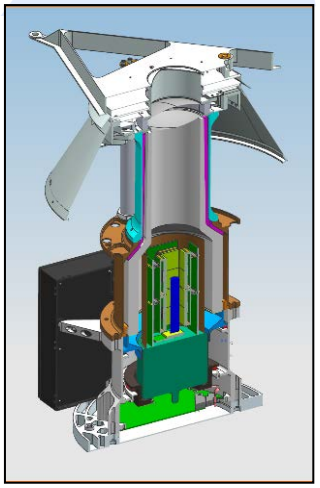
**NuSTAR optics bench**

DTU

JPL

**NuSTAR optics (one rather than two)**

NASA



**Focal plane**

***Build-to-print:***
**CZT detectors**

***New:***
**scatterer**

California Institute of Technology 1891

Lawrence Livermore National Laboratory

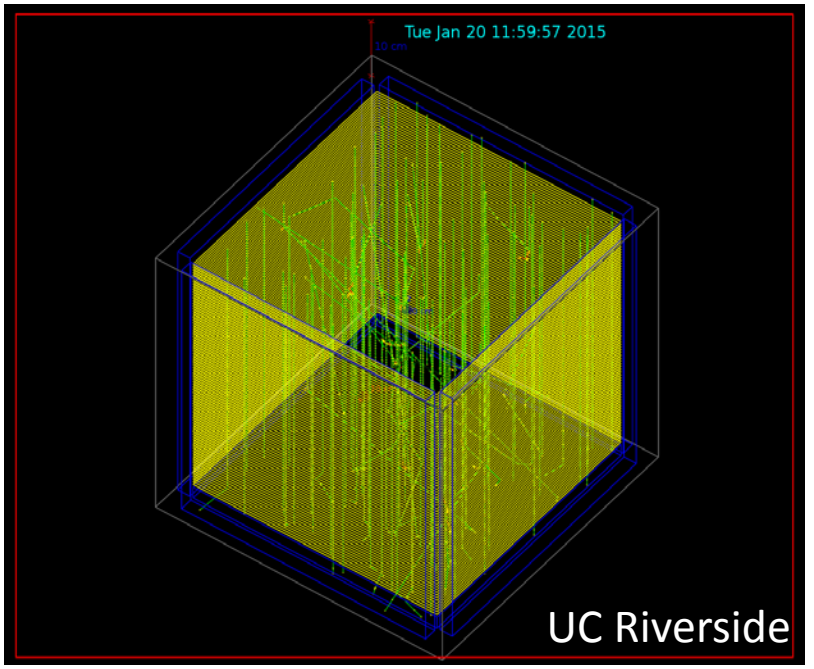
University of California Berkeley 1868

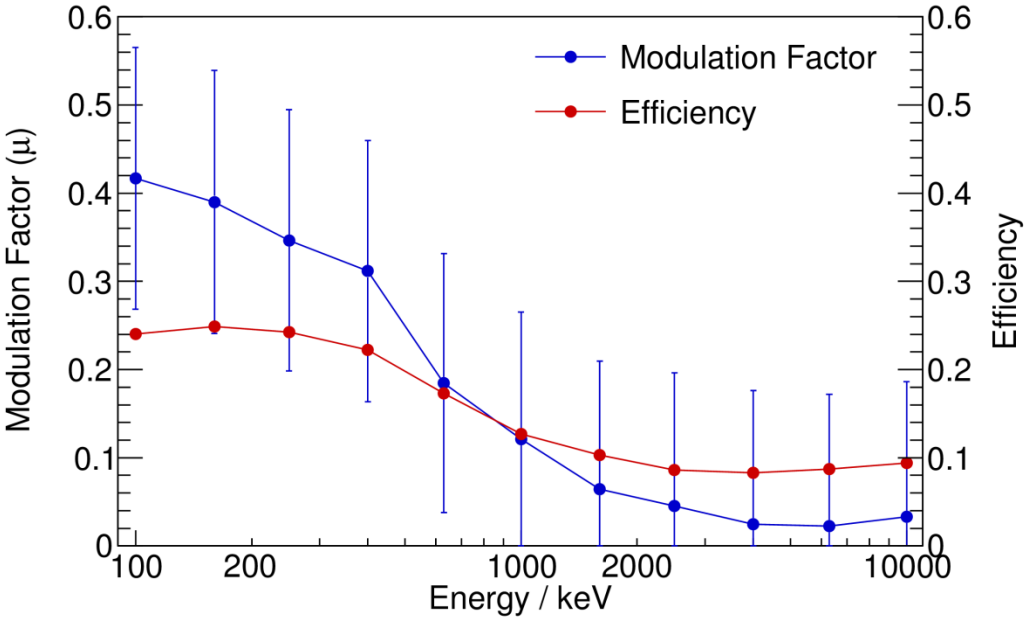
Washington University in St. Louis 1853

***PolSTAR* will use *NuSTAR* technology plus a passive scattering slab to do completely new science.**

# Compton Telescope Concept

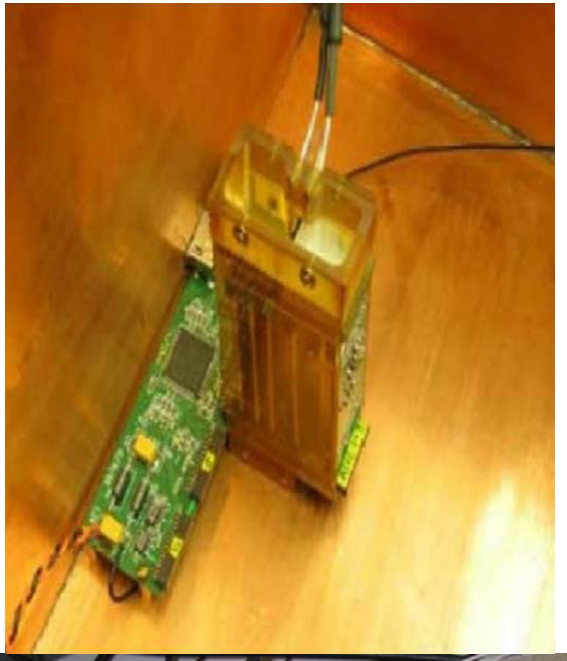
- No focusing optics >100keV
- Use Compton / pair production kinematics to reconstruct photon direction
- Higher backgrounds
- Lower efficiency
- Lower modulation factor
- Large field of view
- Imaging polarimetry
- 80 layers of 150µm Si surrounded by 10mm CZT
- Total area 25,600cm²

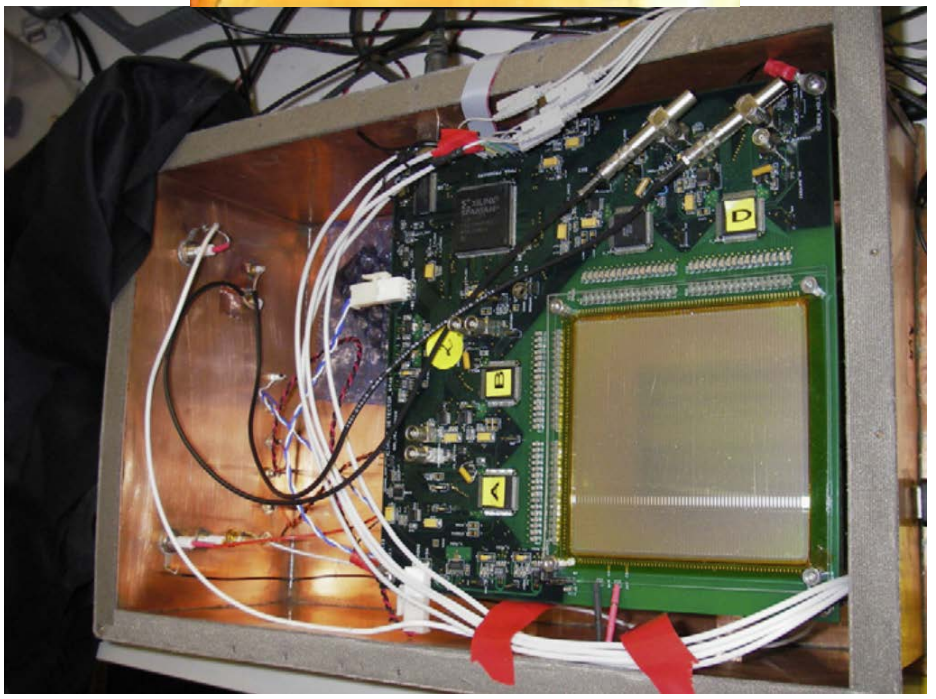


# Si + CZT Compton Telescope Lab-Tests

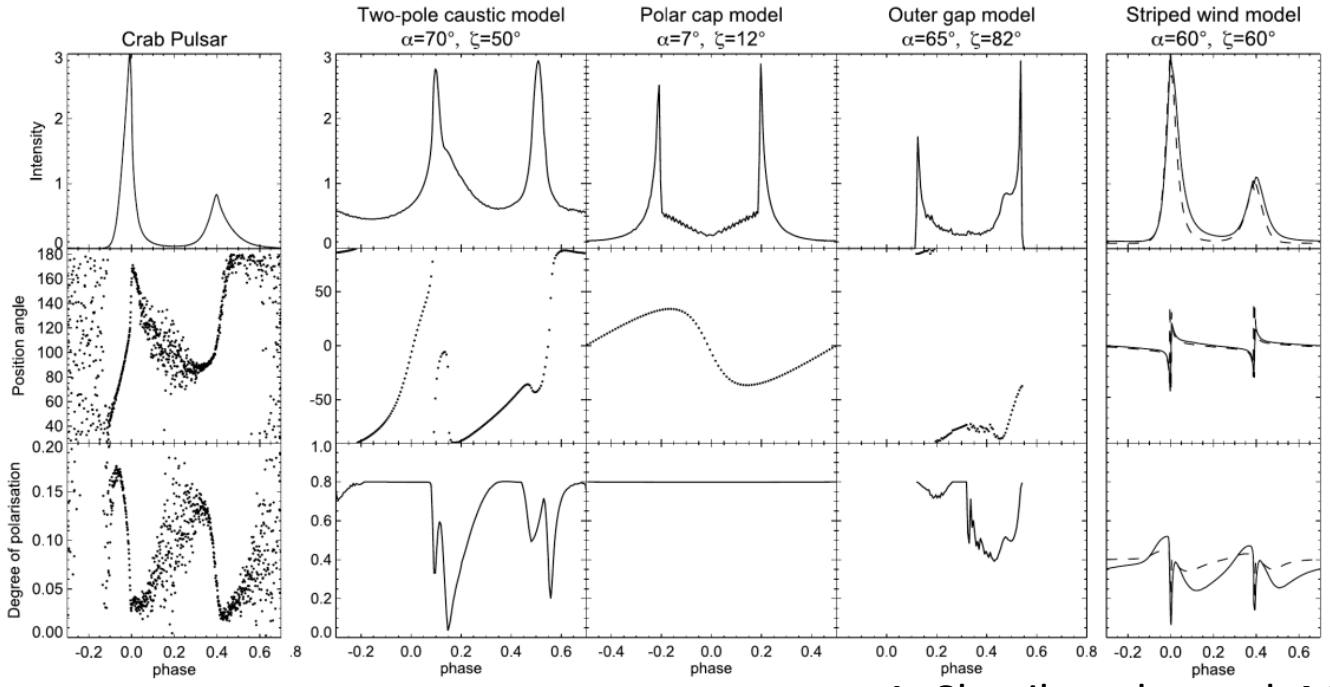
- Built and tested a Si + CZT Compton telescope at Washington U and NRL
- 9x9x0.2cm³ cross-strip Si with 64 strips on each side
- 2x2x0.5cm³ CZT with 64 pixels
- Advantage: Fewer layers ⇒ less overall weight, fewer channels
- Disadvantage: Cannot make use of pair conversion events





M. Subramanian et al, NIM A 682, 2012

# Rotation-Powered Pulsars

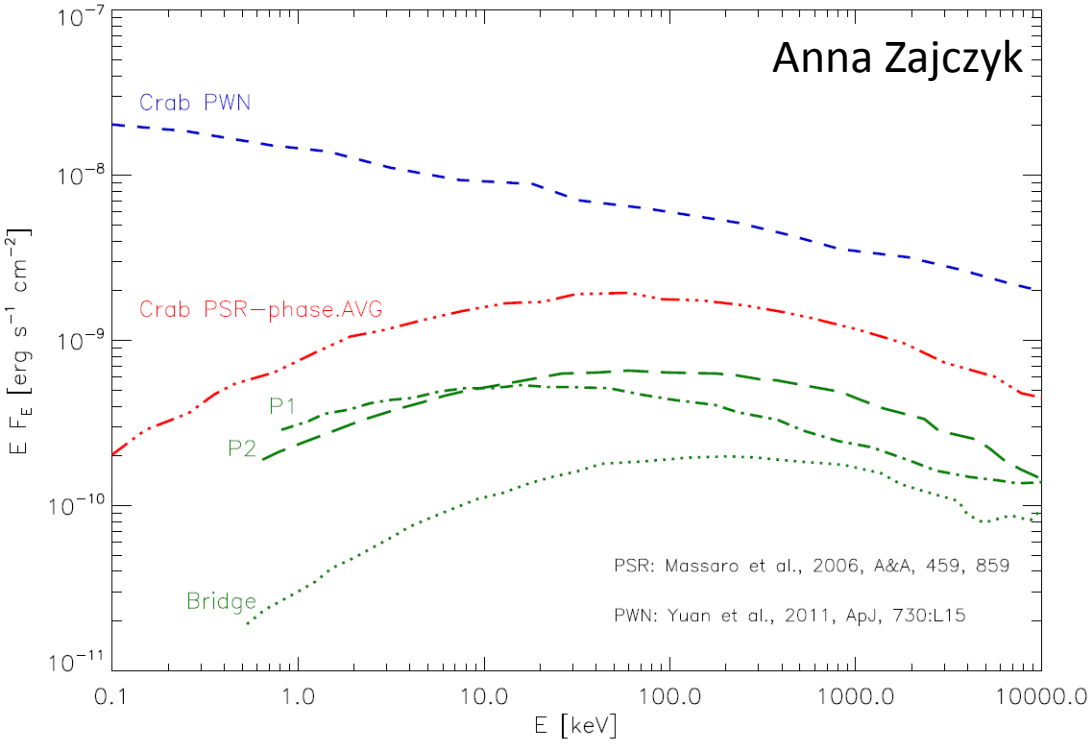



A. Słowikowska et al. MNRAS 397 (2009)

- Emission region still controversial
- Radio emission likely from polar caps
- Gamma-ray emission possibly from outer magnetosphere
- Where does the transition happen?
  $\Rightarrow$ Broad-band polarimetry necessary
- Polarization can break model degeneracies

# The Crab

- Pulsar surrounded by powerful PWN
- PolSTAR cannot spatially resolve the system
- Relative contribution of pulsar much stronger at E>100keV



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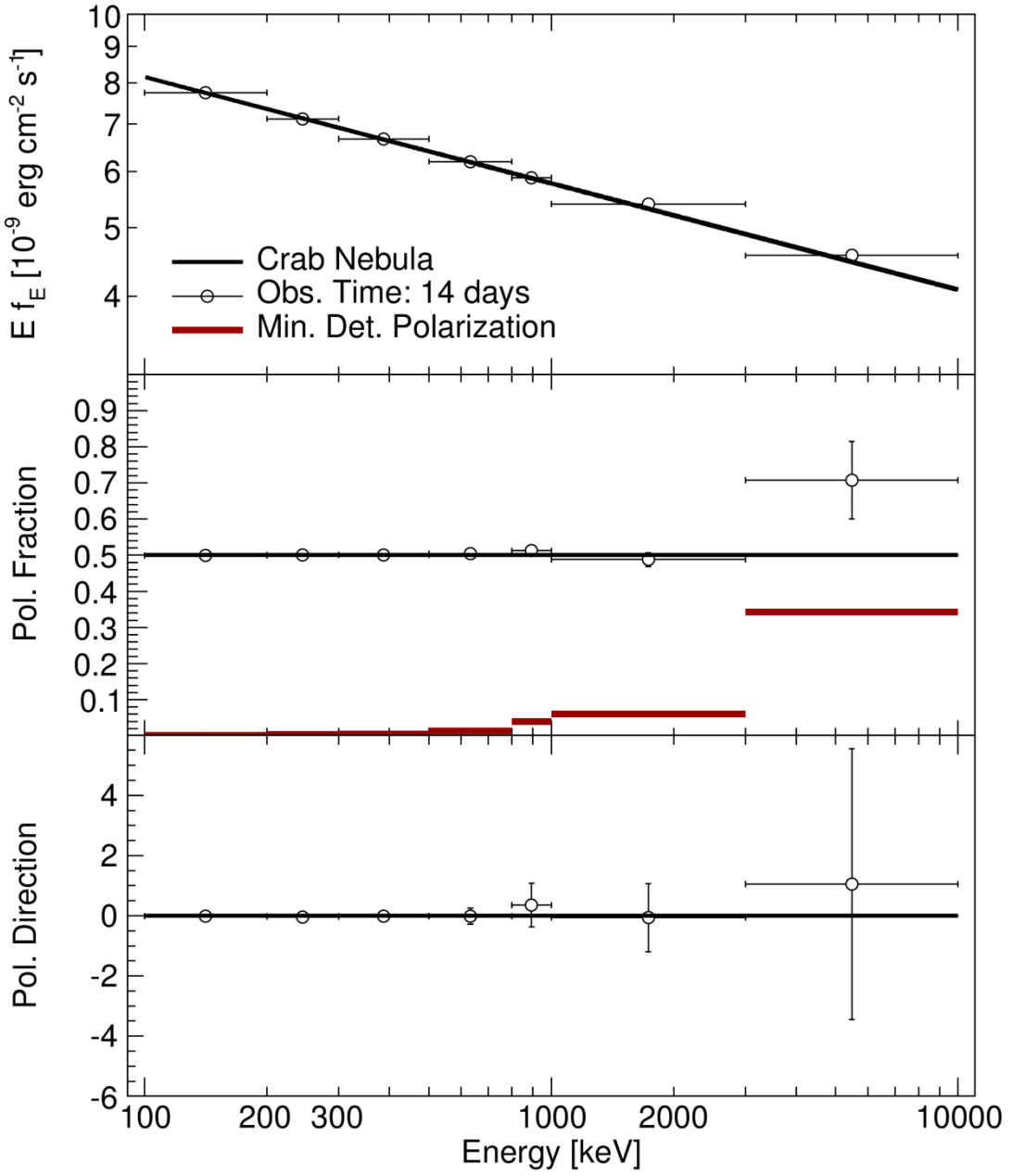
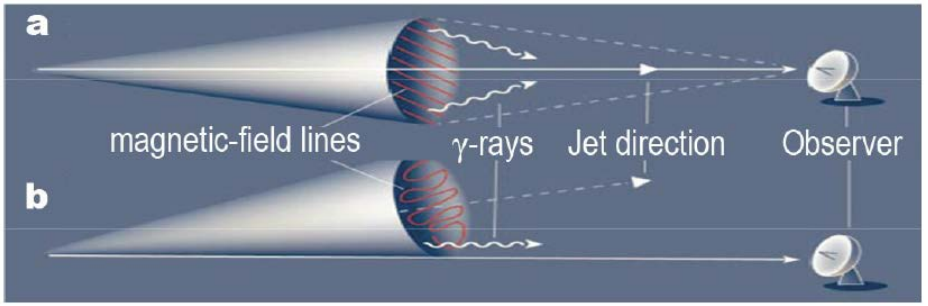
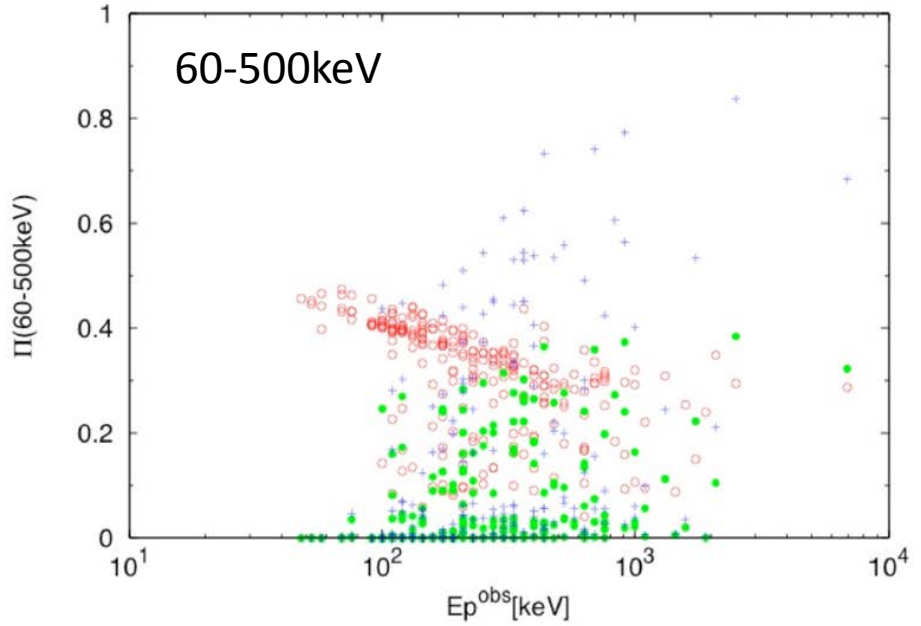
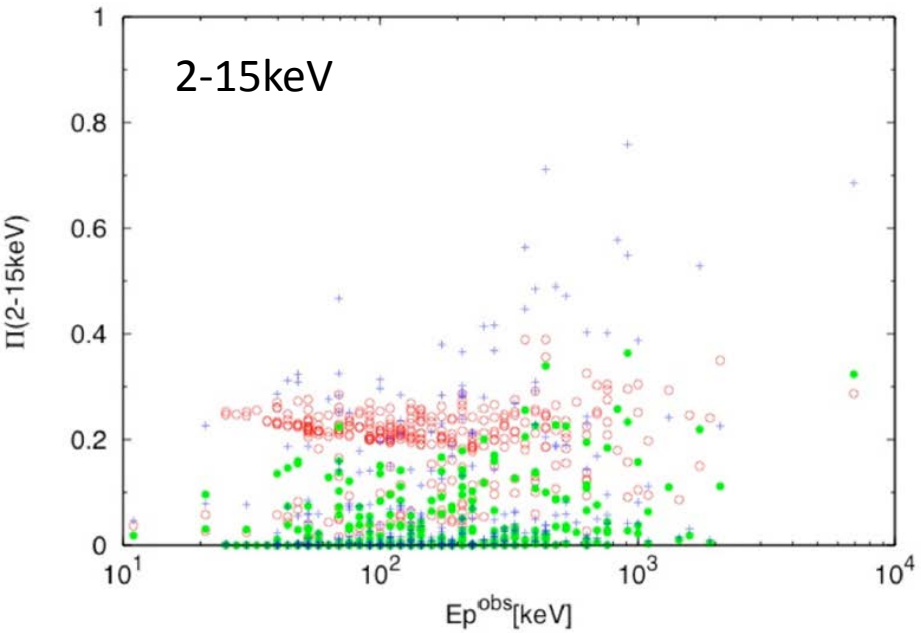


# Gamma-Ray Bursts




- Huge energy dissipation
- Collimated jets pointed towards observer
- Fireball model ⇒ relativistic jet with Lorentz factor >100
- Is there a globally structured magnetic field?
- Emission mechanism: Synchrotron radiation, Compton scattering, … ?
- Models can be distinguished by polarization measurements above and below spectral peak
- Excellent probes of Lorentz violation
- Transient events
  ⇒ Large field of view required

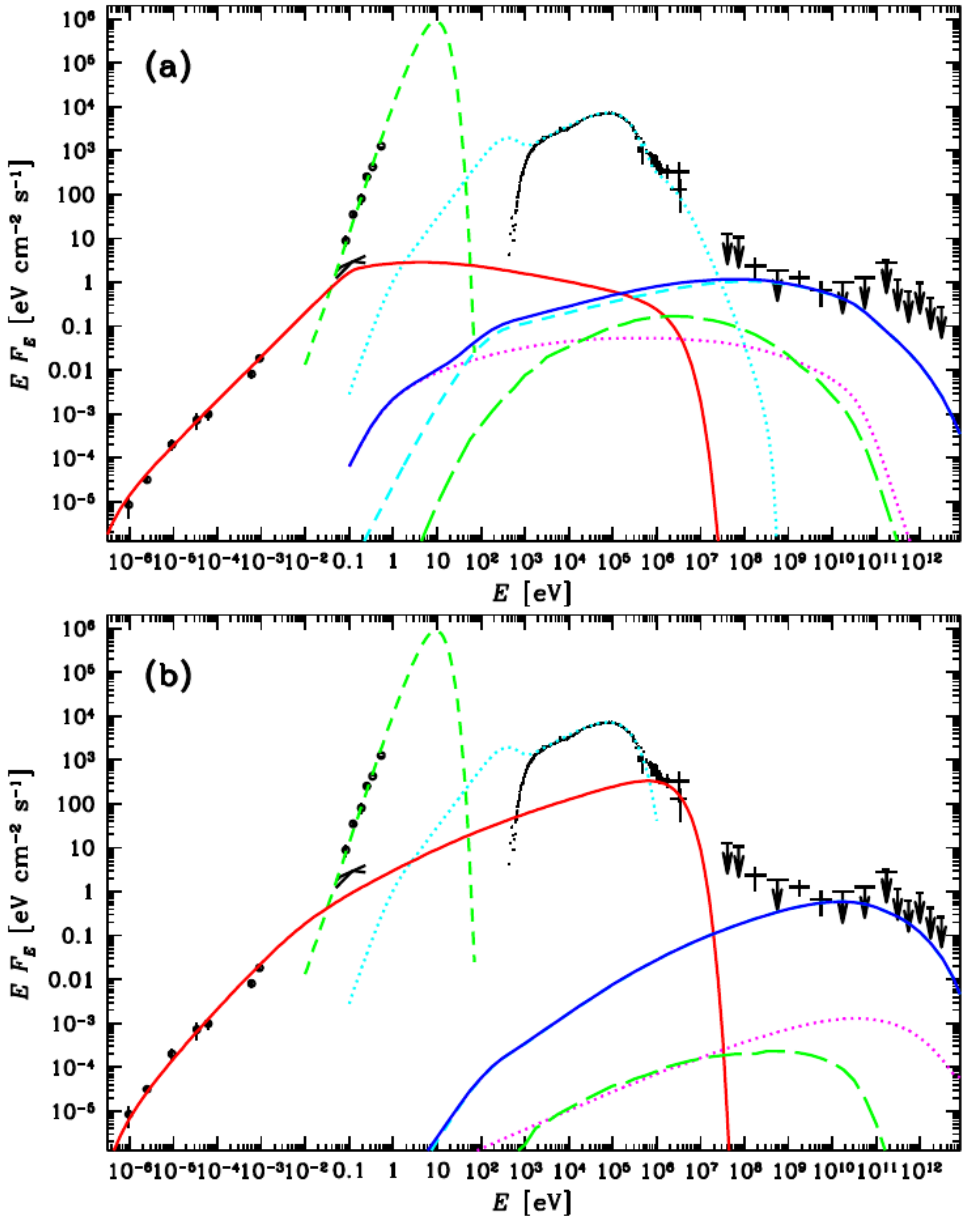



T. Bulik et al. ApJ 395 (1992)

# Cygnus X-1

- Origin of hard power-law tail between 400keV and 2MeV?
  - Synchrotron from jet? (e.g. Zdziarski et al)
  - Coronal emission? (Romero et al.)
- INTEGRAL indicates high fraction of polarization ~67% above 400keV
- Optimized Compton telescope can deliver very detailed polarization information
- Probes a different component than X-ray polarimetry
- An optimized Compton telescope can deliver very detailed polarization information




A.A. Zdziarski et al. MNRAS 442 (2014)

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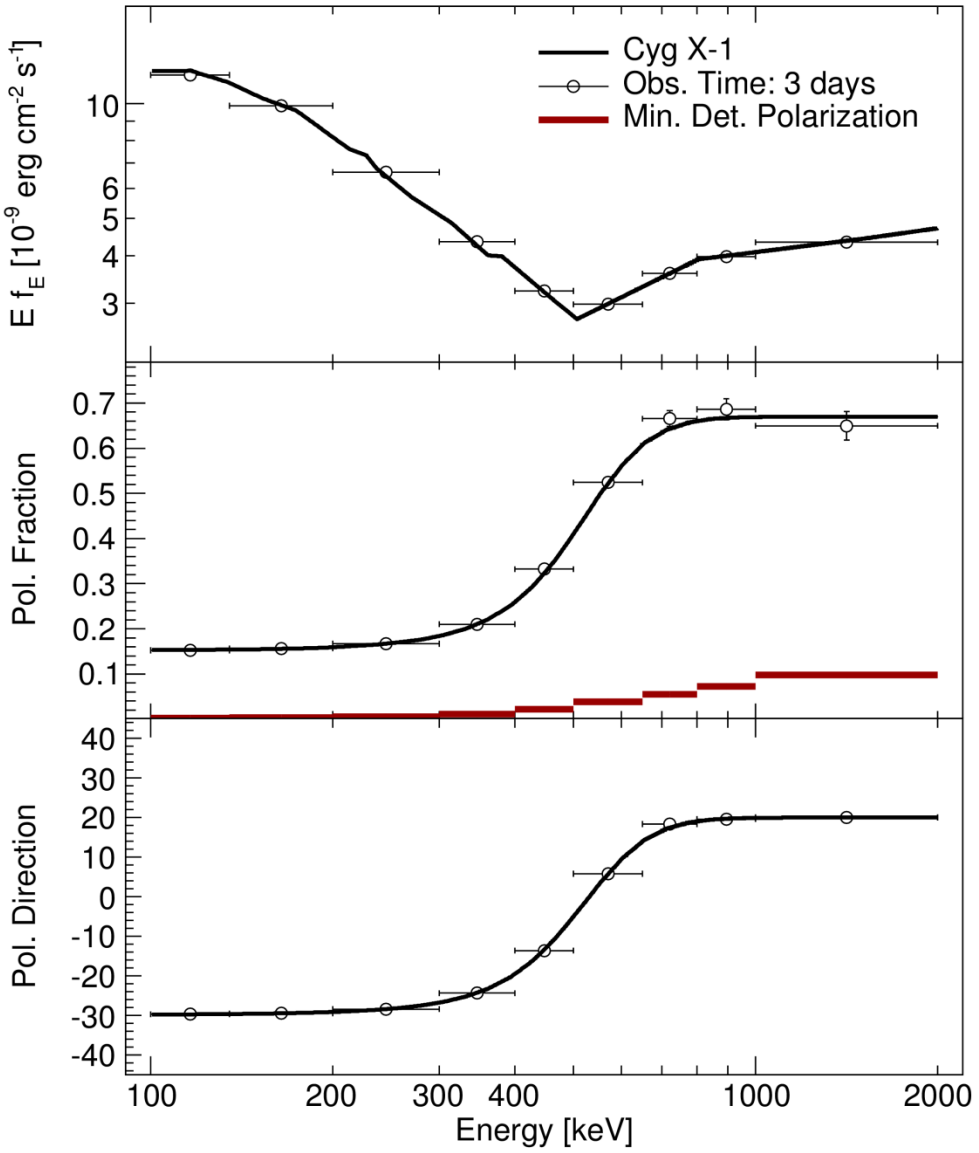

# Summary

- X-ray and gamma-ray polarimetry …
  - reveals emission mechanisms
  - provides geometrical information about unresolvable objects
- Below 100keV: focusing optics, above: Compton telescopes
- Large field of view ⇒ Catch transient events, such as GRBs
- Imaging polarimetry ⇒ Create polarization maps of extended objects, such as SNR, PWN
- Higher energies often probe a completely different spectral component than X-ray polarimetry
- High energy polarimetry can constrain higher-order Lorentz violating operators
- Photon splitting in magnetars leads to polarization at high energies ⇒ test of fundamental physics

⇒ **X-ray and gamma-ray polarimetry complement one another**

⇒ **Gamma-ray polarimetry provides a unique science case**