

Energy-dependent polarization of Gamma-Ray Bursts' prompt emission with POLAR and POLAR-2

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Nicolas De Angelis¹ for the POLAR and POLAR-2 collaborations²

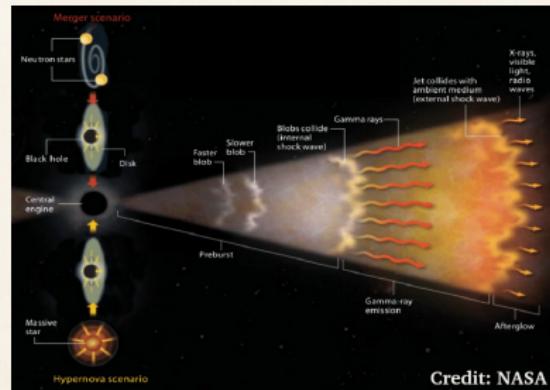
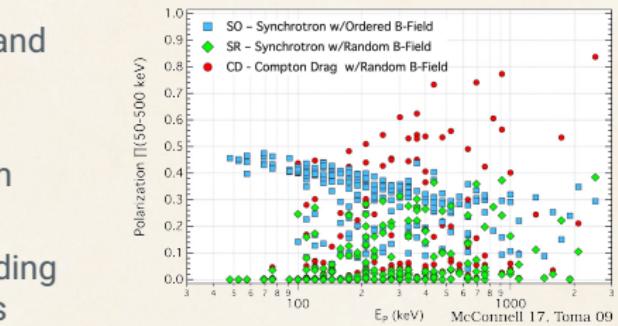
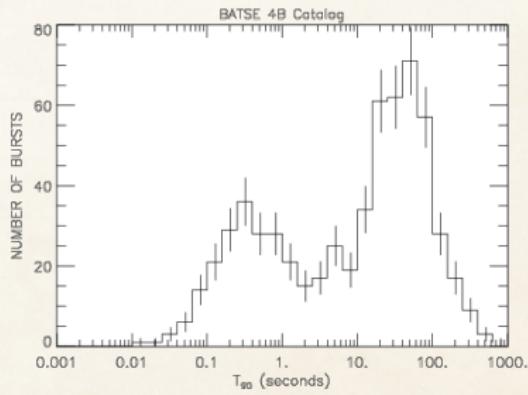
DPNC, University of Geneva, Switzerland

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²<https://www.astro.unige.ch/polar/collaboration>
<https://www.unige.ch/dpnc/polar-2>

Gamma-Ray Bursts paradigm

- Bright and short transient event in γ band followed by an afterglow (in all wavelengths)
- Extragalactic, 2 categories: short (from BNS) and long (from SN)
- Polarization brings a better understanding of the jet and magnetic field structures



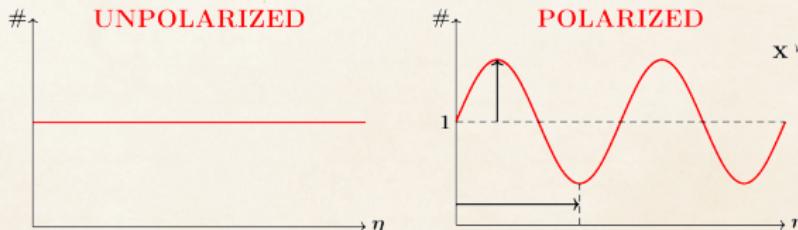
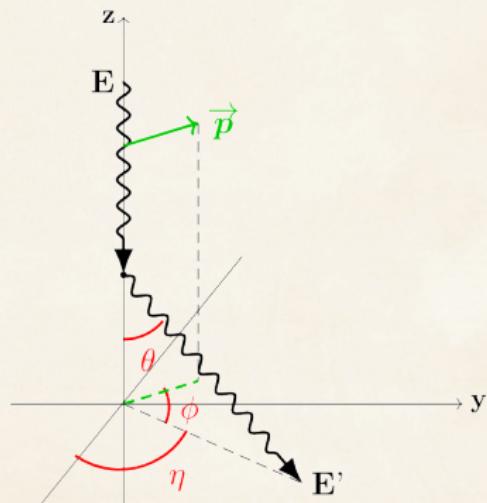
Polarimetry with the Compton scattering

Compton scattering can be used to determine the polarization of a source:

- Azimuthal scattering angle distribution provides information on polarization degree and angle
- So called modulation curved, parametrized by the Klein-Nishina cross-section:

$$\frac{d\sigma}{d\Omega} = \frac{r_e^2}{2} \left(\frac{E'}{E} \right)^2 \left[\frac{E'}{E} + \frac{E}{E'} - 2 \sin^2(\theta) \cos^2(\phi) \right]$$

- Relative amplitude \leftrightarrow PD, phase \leftrightarrow PA



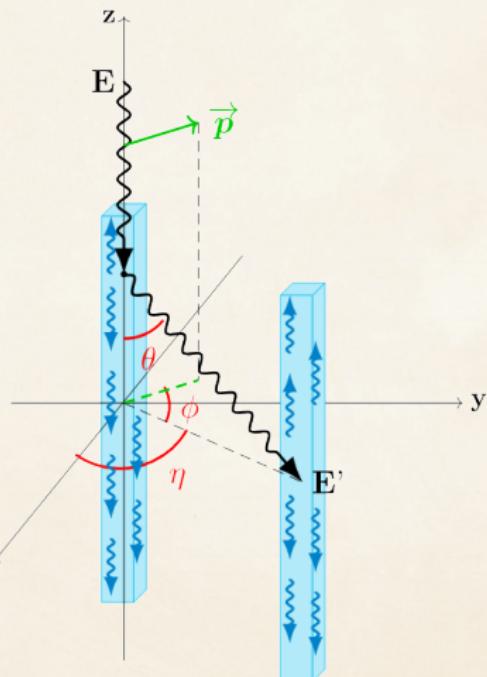
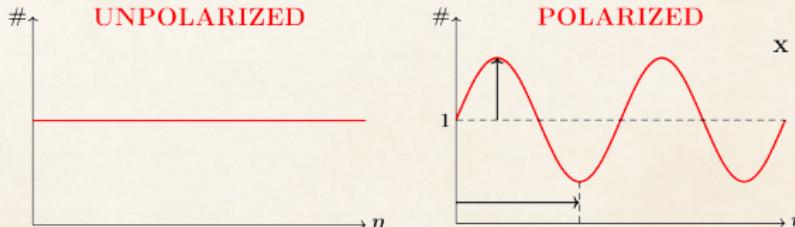
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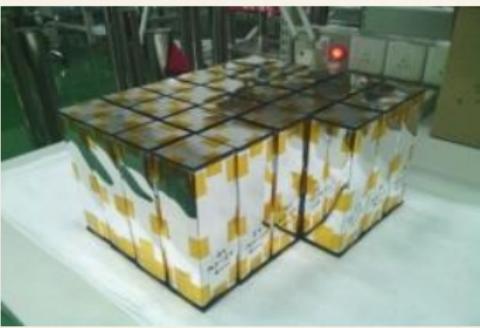
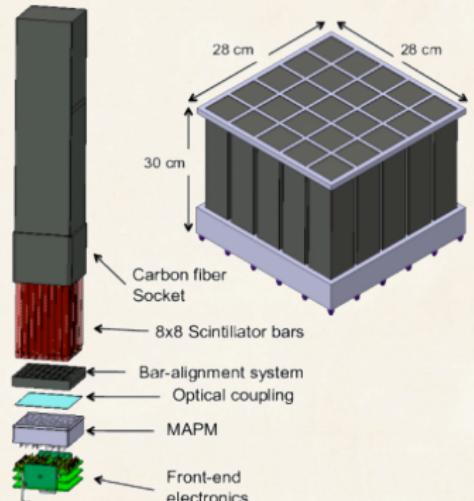
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- Relative amplitude \leftrightarrow PD, phase \leftrightarrow PA
- **A segmented array of scintillators can be used to measure the scattering angle distribution (aka modulation curve)**



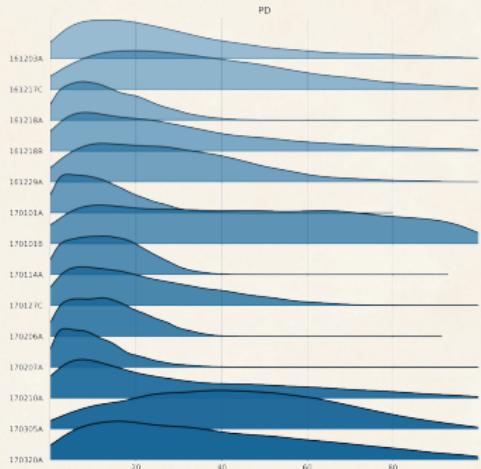
The POLAR instrument

- POLAR was a dedicated gamma polarimeter composed of a 40×40 scintillator array
- Divided in 5×5 modules each made of 64 plastic scintillator bars ($176 \times 5.8 \times 5.8 \text{ mm}^3$, EJ-248M), each module being readout by Multi-Anode PMTs
- Optimized for Compton scattering in the 50-500keV range thanks to its low-Z scintillators
- 30kg instrument, half-sky FoV, $\sim 300\text{cm}^2$ effective area at 400 keV
- Design described in Produit et al. 2018 (DOI: [10.1016/j.nima.2017.09.053](https://doi.org/10.1016/j.nima.2017.09.053))
- Launched in Sept 2016 on the Tiangong-2 Chinese space lab for 6 months of operation

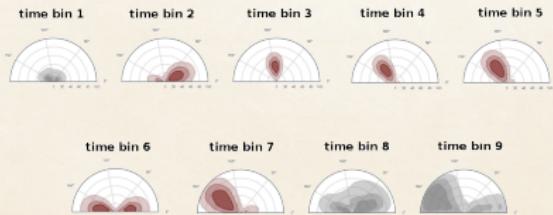


POLAR energy integrated and time resolved results

- Catalog of 14 GRBs analysed, results show a low or null polarization degree (excluding synchrotron emission models from toroidal magnetic field, compatible with photospheric emission model and other synchrotron models)
- High quality analysis of 5 GRBs published in Nat Astron 3, 258–264 (2019)
- Time resolved analysis show a hint of quickly evolving polarization angle that washes out polarization degree on time integrated analysis \implies need more statistics to make proper time resolved analysis

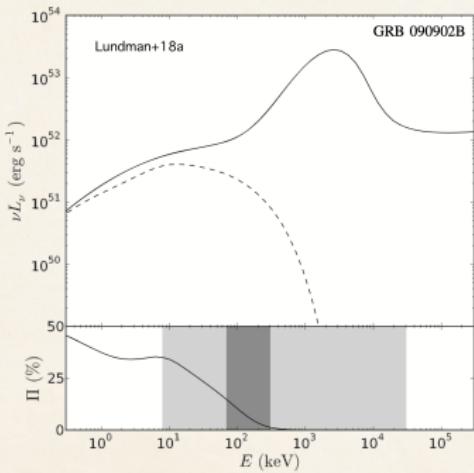
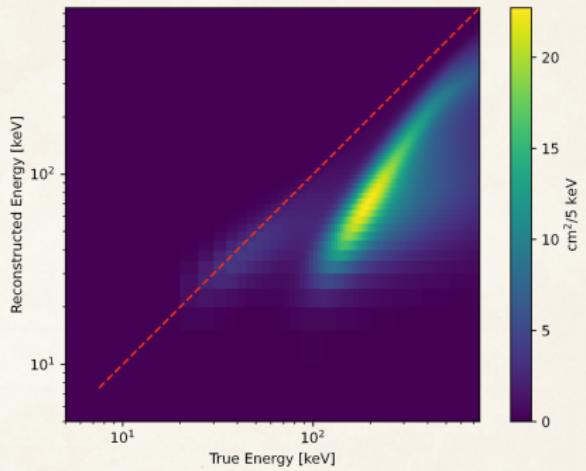


A&A 644, A124 (2020)

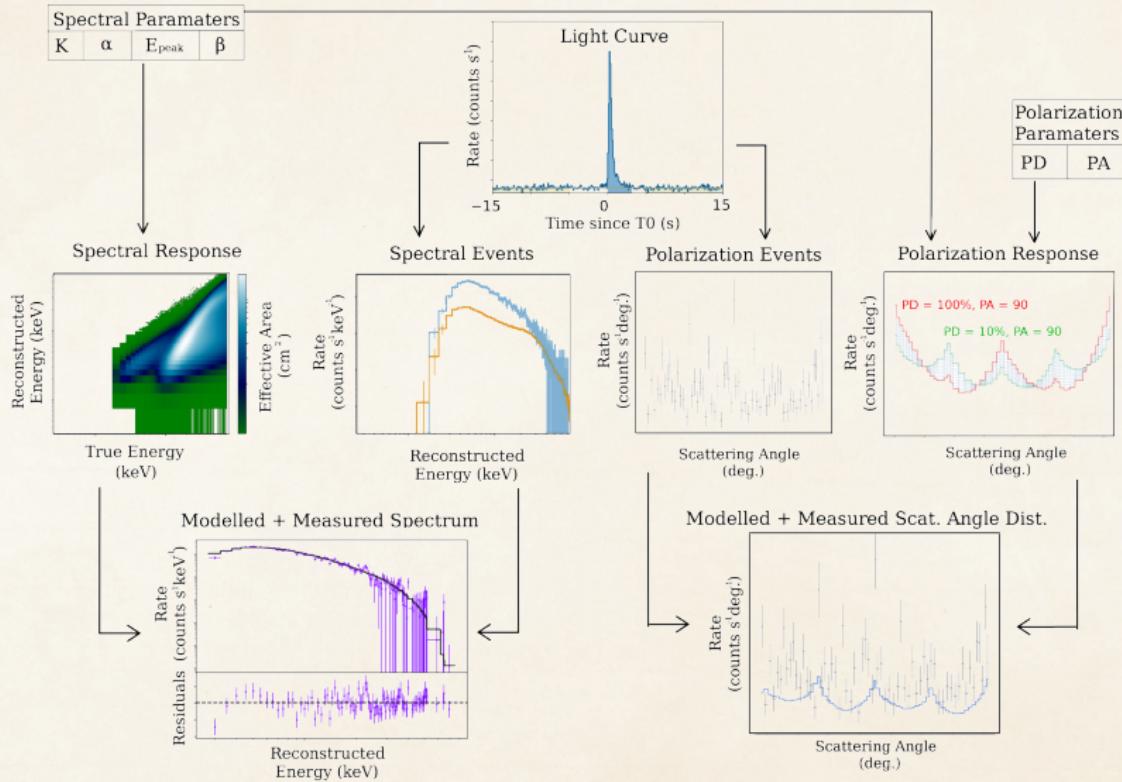


A&A 627, A105 (2019)

Energy dependence of prompt emission's polarization



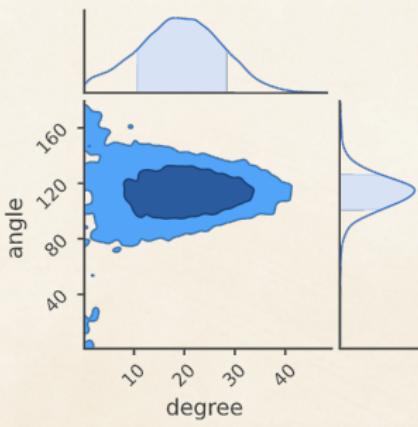
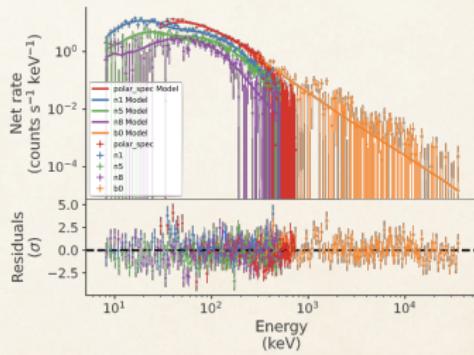
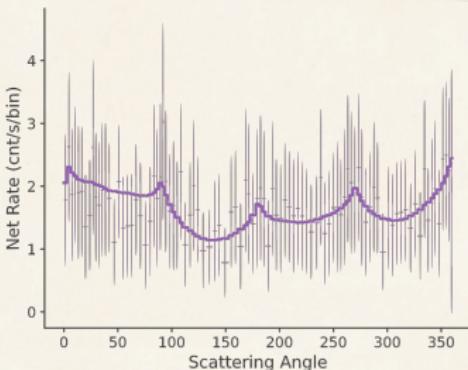
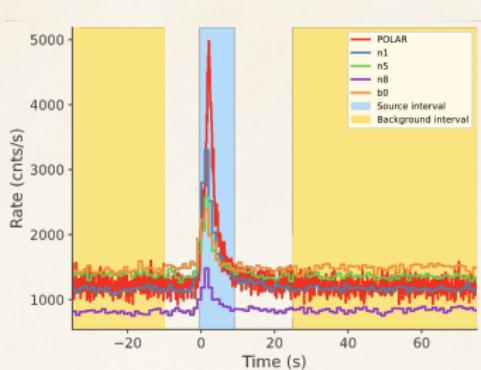
Joint polarization-spectral GRB analysis method



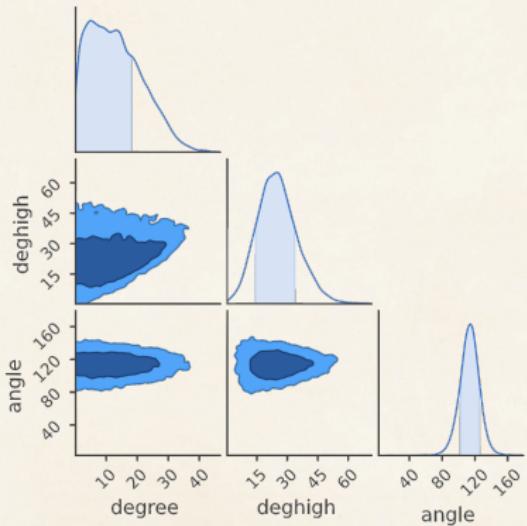
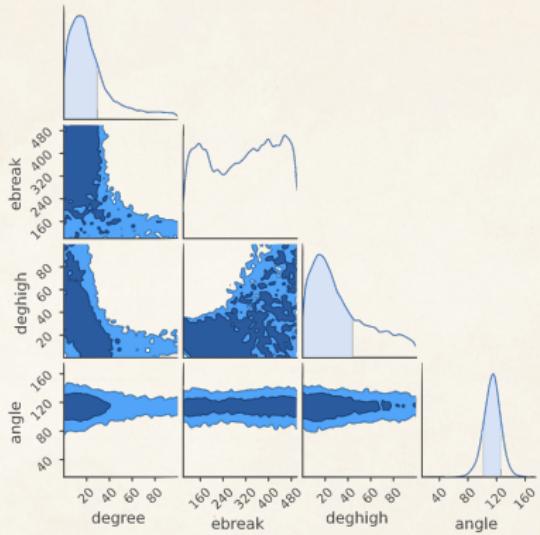
<https://github.com/threeML/threeML>

A&A 644, A124 (2020)

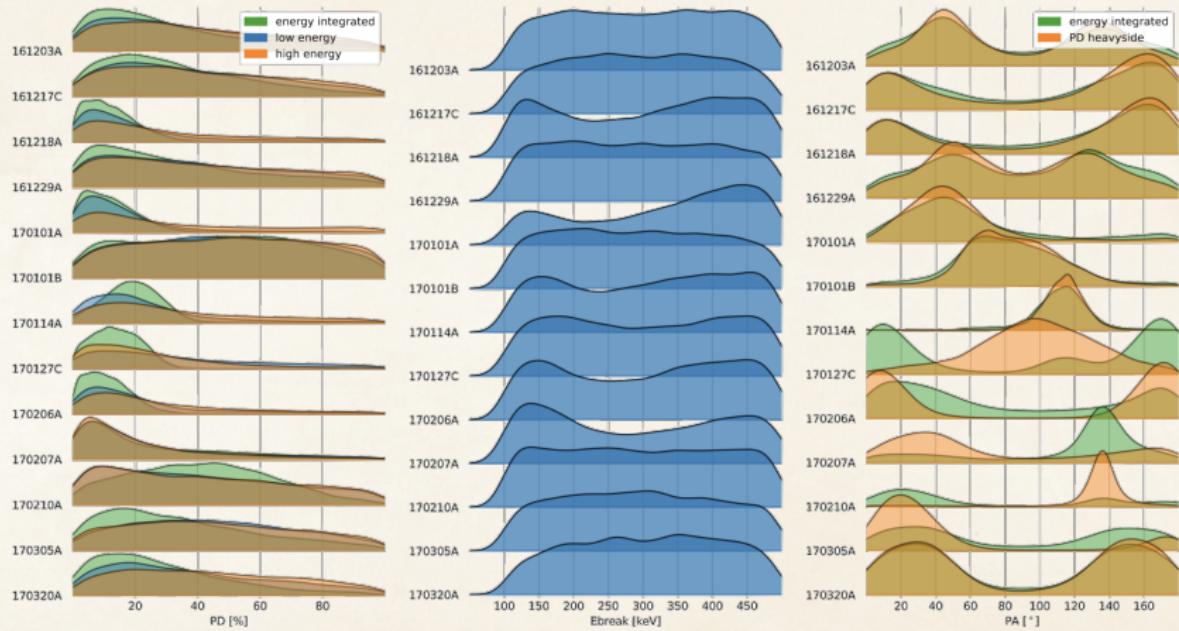
Energy integrated results: GRB170114A



PD Energy resolved results on GRB170114A

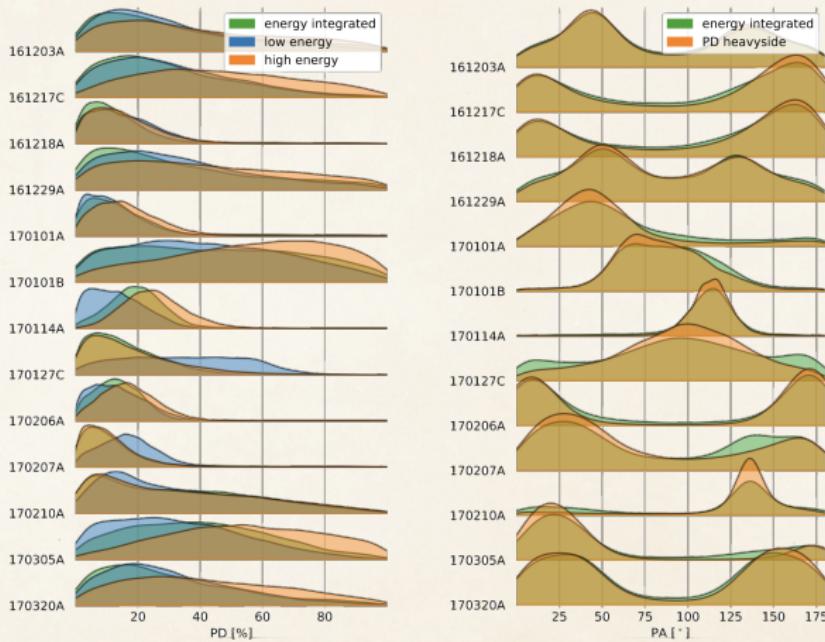


PD heaviside fitting on the POLAR catalog



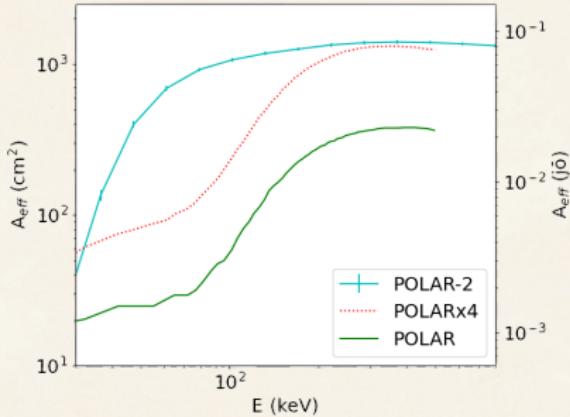
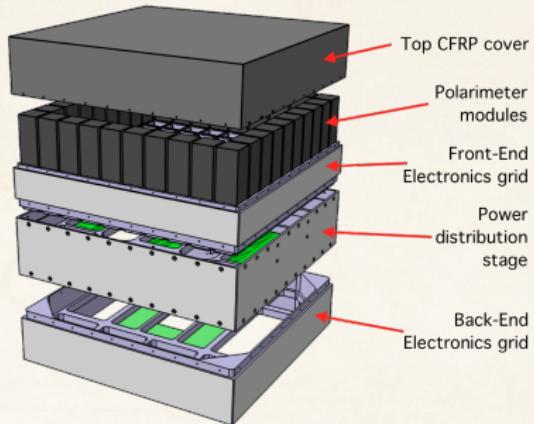
PD heaviside fitting on the POLAR catalog

Fixing the energy break at 150 keV:



Ongoing work: trying other energy dependent models (e.g. linear fit) and trying to fit the PA vs. energy

Future prospects: the POLAR-2 mission



See poster by Produit et al. [PGA1-20] about the POLAR-2 instrument
4 times more channels, 10 times more sensitivity
Launch to the CSS at the end of 2025
UniGe (Switzerland), IHEP (China), NCBJ (Poland), MPE (Germany)



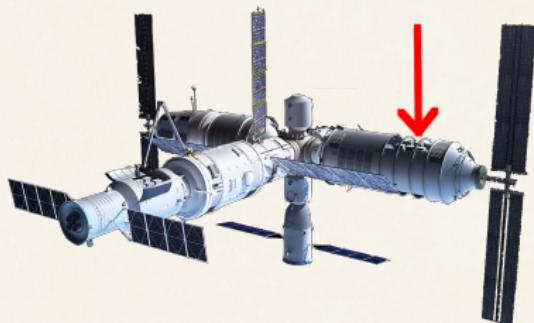
Next step: predicting POLAR-2's sensitivity to polarization energy dependence

Backup slides

POLAR-2 et al.: X-ray polarimeter and γ -ray spectrometers

Two other payloads proposed to the China Space Station (CSS):

X-ray polarimeter (LPD)
& Spectrometer (BSD)



➤ Low-energy Polarization Detector:

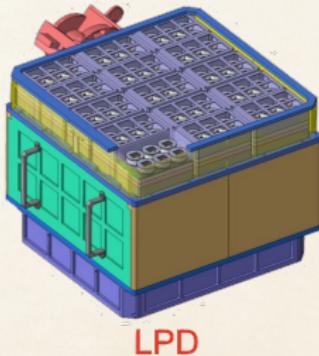
LPD

- ~2-10 keV X-ray polarimetry

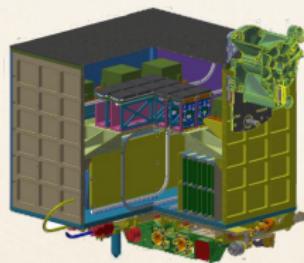
➤ Broad energy-band Spectrum Detector: BSD

- ~10-2000keV
- Accurate GRB localization and spectroscopy for HPD and LPD

➤ Status: Selected, to be adopted



LPD



BSD

from Jianchao Sun, IHEP