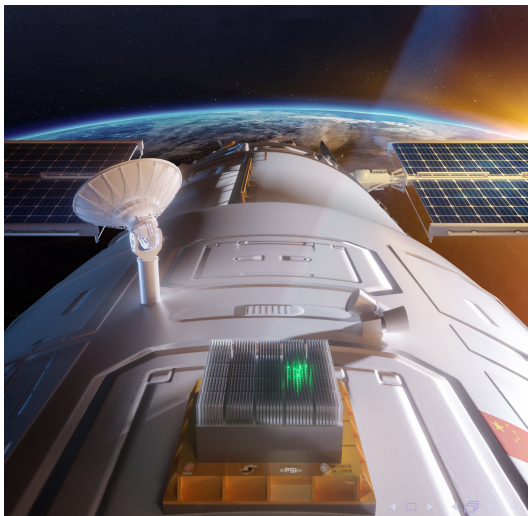
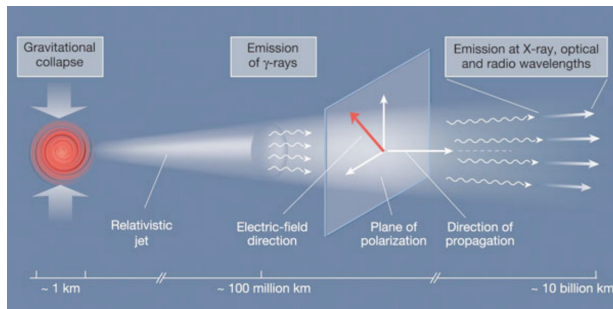


Gamma-Ray Polarization Results of the POLAR Mission and Future Prospects

Merlin Kole on behalf of the POLAR & POLAR-2 Collaboration



Gamma-Ray Burst Polarimetry



E. Waxman, Nature 423 (2006) 388

- Measure polarization of the γ -ray prompt emission of GRBs
- Unique probe into the jet environment
- Simplified: synchrotron would give high polarization, thermal emission no/low polarization
- Overview: Kenji Toma arXiv:1308.5733 and R. Gill et al. arXiv:1811.11555

Gamma-Ray Burst Polarimetry

No clear results from previous measurements:

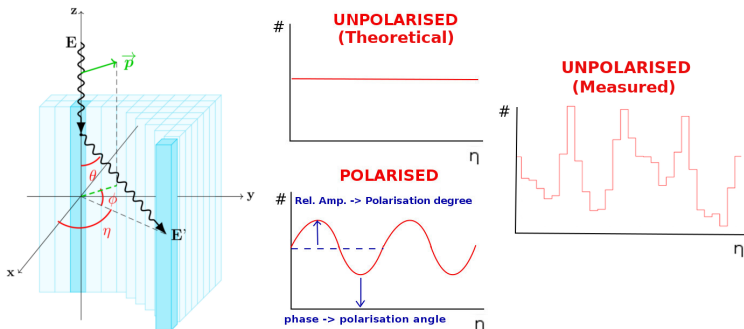
GRB	Instr./Sat.	Pol. (%)	Remark
160530A	COSI	$< 46\%$	low statistics
110721A	GAP/IKAROS	84^{+16}_{-28}	Constant Pol. Angle
110301A	GAP/IKAROS	70 ± 22	Constant Pol. Angle
100826A	GAP/IKAROS	27 ± 11	Pol. Angle changes by $\approx 90^\circ$
021206	RHESSI	80 ± 20	non dedicated instrument
021206	RHESSI	41^{+57}_{-44}	non dedicated instrument
140206A	IBIS/INTEGRAL	≥ 48	non dedicated instrument
061112	IBIS/INTEGRAL	≥ 60	non dedicated instrument
041219A	IBIS/INTEGRAL	$\leq 4/43 \pm 25$	non dedicated instrument
041219A	SPI/INTEGRAL	98 ± 33	non dedicated instrument
960924	BATSE/CGRO	≥ 50	non dedicated instrument
930131	BATSE/CGRO	≥ 35	non dedicated instrument

- Early measurements performed by non-dedicated instruments
- Several measurements shown to be wrong
- See M. McConnell, New Astro Rev. Vol. 76, 2017

Compton Polarimetry

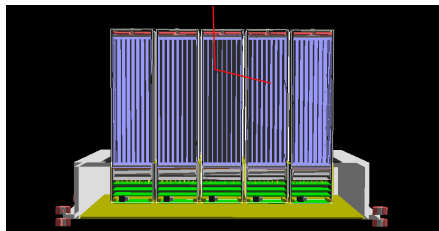
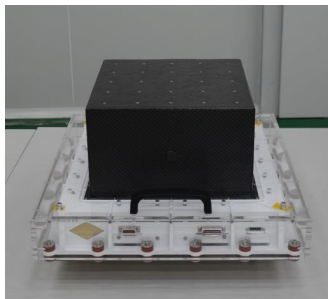
- Requires the detection of the scattering angle of photons
- Typical low efficiency
- Easy to get systematic effects in data
- Worse for GRBs: unknown incoming direction \rightarrow requires wide Field of View \rightarrow worse signal to noise

$$\frac{d\sigma}{d\Omega} = \frac{r_o^2}{2} \frac{E'^2}{E^2} \left(\frac{E'}{E} + \frac{E}{E'} - 2 \sin^2 \theta \cos^2 \phi \right). \quad (1)$$



The POLAR Detector

- Measures scattering angle using a scintillator array
- Large effective area of $\approx 300\text{cm}^2$ at 400 keV
- Small pixels allows for high precision scattering angle measurements
- Uniform effective area gives us a large Field of View
- Full description of the instrument:
N. Produit et al. arXiv:1709.07191

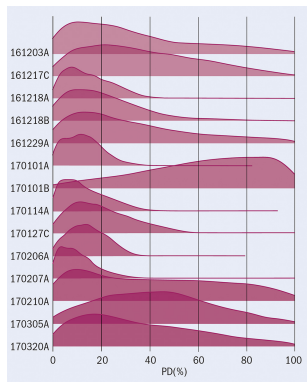


POLAR



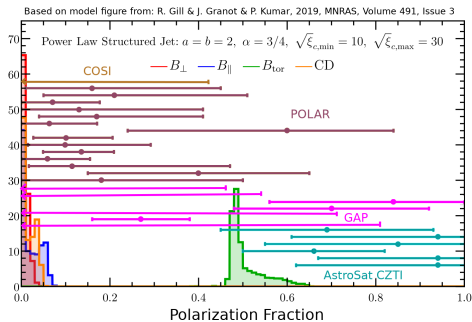
- TG-2 Chinese Space Lab launched on September 15th 2016
- POLAR took data until April 2017
- Detected 55 GRBs as well as 2 pulsars: see contribution from Hancheng Li "Polarization measurements of the Crab Pulsar with POLAR"

Summary POLAR results



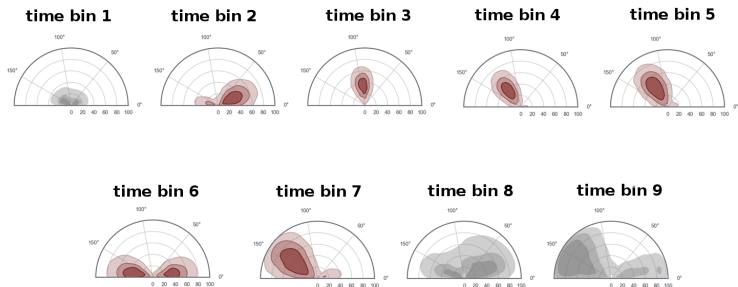
M. Kole et al. A&A 644, A124 (2020)

POLAR data & response public:
www.astro.unige.ch/polar/



- Results compatible with unpolarized emission
- Appear to rule out synchrotron emission from a toroidal magnetic field
- Agree with all other models
- Does not match with recent results from AstroSat CZTI

Time resolved study



- Results hint that the polarization angle changes within single pulse GRBs
- Low polarization could be an artifact of this angular evolution
- Only observed for both single pulse GRBs, overall full pulses appear unpolarized
- J.M. Burgess et al. *'Time-Resolved GRB Polarization with POLAR and GBM'* A&A 2019
- Conclusion: we need more statistics

POLAR-2



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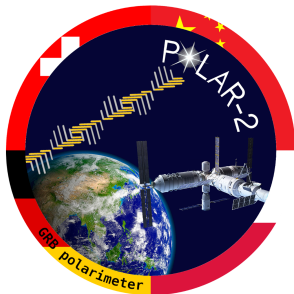
FACULTÉ DES SCIENCES



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



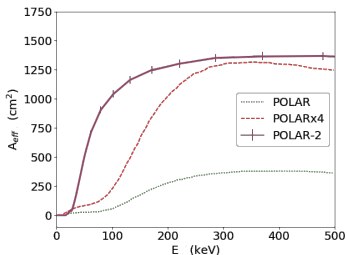
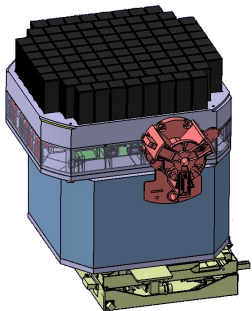
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- POLAR results raised more questions
- We need a significantly more sensitive detector: POLAR-2
- Launch approved to go to the CSS in early 2024
- <https://www.unige.ch/dpnc/polar-2>

POLAR-2

- Increase size by factor 4
- Gain another factor 2 to 3 in sensitivity by improving design
- Details on technical design in contribution by Nicolas de Angelis:
"Development and science perspectives of the POLAR-2 instrument: a large scale GRB polarimeter"
- Add spectrometers to provide detailed spectrum and location for all GRBs
- Very large sensitivity → can easily detect GRBs like 170817A
- Will send real time (several seconds) alerts to ground



Summary and Outlook



- POLAR answered some questions on GRB prompt polarization
- Raised more questions...
- POLAR-2 under construction right now
- Will provide detailed polarization measurements for 50 GRBs/year from 2024
- Will provide alerts to all on ground instruments within seconds of detection

