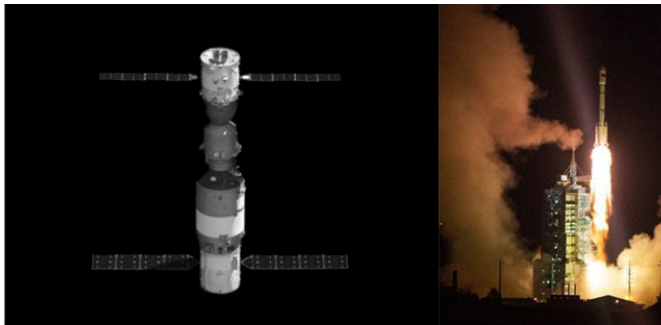


First Results of POLAR: A dedicated Gamma-Ray Burst Polarimeter

Tancredi Bernasconi on behalf of the POLAR collaboration



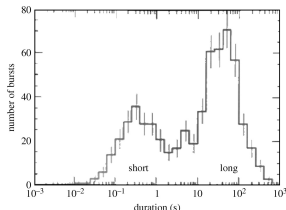
Credit: South China Morning Post



Geneva, August 24th, 2017

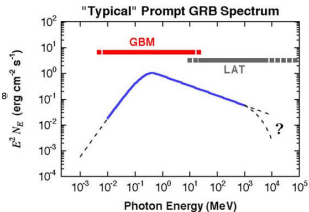
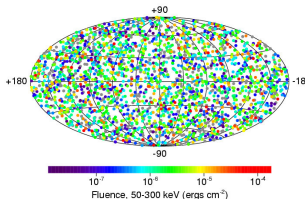
Gamma-Ray Burst

- Burst lasting from 0.3s to several minutes
- Light curves are very variable in shapes
- Uniformly distributed in the sky: extra-galactic event
- Most energetic events in the universe since the big bang



Scott D Barthelmy, *Philos Trans A Math Phys Eng Sci.* (2007)

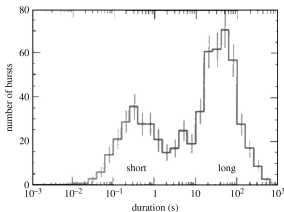
2704 BATSE Gamma-Ray Bursts



G. Fishman et al., BATSE, CGRO, NA source: <http://polywww.in2p3.fr>

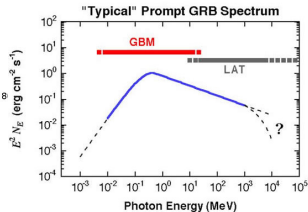
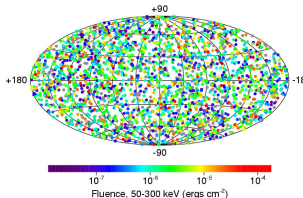
Gamma-Ray Burst

- First detection of a GRB almost 50 years ago today
- Timing, Direction and Energy spectrum measured in great detail
- Two parameters remain: polarisation degree and polarisation angle



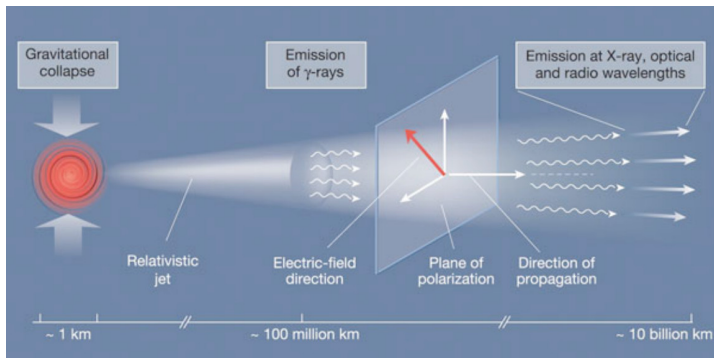
Scott D Barthelmy, *Philos Trans A Math Phys Eng Sci.* (2007)

2704 BATSE Gamma-Ray Bursts



G. Fishman et al., BATSE, CGRO, NA source: <http://polywww.in2p3.fr>

Gamma-Ray Burst Polarimetry



E. Waxman, Nature 423 (2006) 388

- Many models exist with many different predictions on the polarization parameters
- See for example: Kenji Toma arXiv:1308.5733
- Polarisation holds information on emission process, e.g. synchrotron emission or photospheric emission or...
- Also on emission region, strong magnetic fields? **Highly ordered?**

Gamma-Ray Burst Polarimetry

Previous measurements were performed

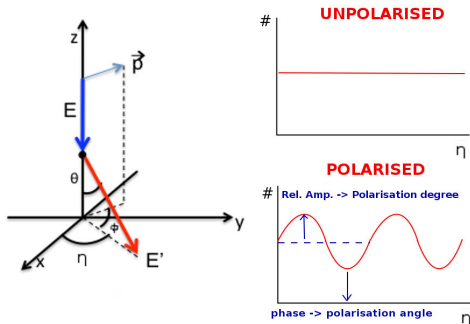
GRB	Instr./Sat.	Pol. (%)	Remark
160530A	COSI	$<53\%$ (90% UL)	statistics dominated
151006A	AstroSat	polarised	systematics dominated?
110721A	GAP/IKAROS	84^{+16}_{-28}	Constant Pol. Angle
110301A	GAP/IKAROS	70 ± 22	Constant Pol. Angle
100826A	GAP/IKAROS	27 ± 11	Pol. Angle changes by $\approx 90^\circ$
021206	RHESSI	80 ± 20	systematics
021206	RHESSI	41^{+57}_{-44}	systematics
140206A	IBIS/INTEGRAL	≥ 48	-
061112	IBIS/INTEGRAL	≥ 60	
041219A	IBIS/INTEGRAL	$\leq 4/43 \pm 25$	Changing Angle and Degree
041219A	SPI/INTEGRAL	98 ± 33	Inconsistent with IBIS
960924	BATSE/CGRO	≥ 50	-
930131	BATSE/CGRO	≥ 35	-

- Most measurements performed by non-dedicated instruments
- Non of the measurements is really constraining
- Required: A large catalogue of GRB constraining measurements

Compton Polarimetry

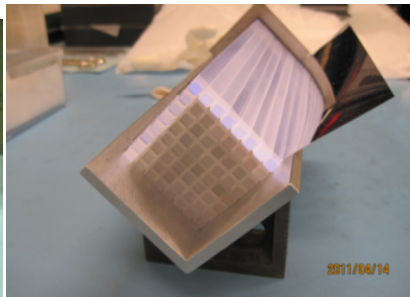
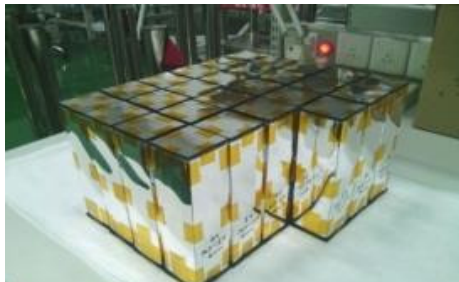
- Azimuthal scattering angle dependence on polarisation
- Figure of merit = μ_{100} : Modulation measured for a 100% polarized incoming beam
- Second figure of merit = MDP: Minimum level of polarization distinguishable from an unpolarized flux with (typical) 3σ certainty

$$\frac{d\sigma}{d\Omega} = \frac{r_0^2}{2} \frac{E'^2}{E^2} \left(\frac{E'}{E} + \frac{E}{E'} - 2 \sin^2 \theta \cos^2 \phi \right). \quad (1)$$



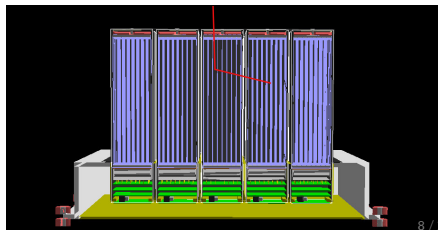
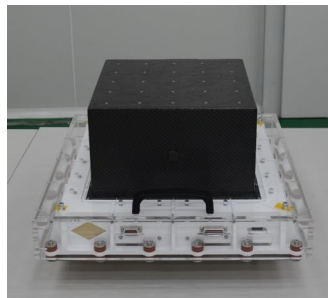
POLAR design

- POLAR uses a segmented scintillator array to measure the Compton scattering angle
- In total 1600 plastic scintillators, $6 \times 6 \times 176$ mm, EJ-248M
- Plastic scintillators optimise the cross section for Compton scattering in the 50-500 keV energy range
- Plastic scintillators allow for a relatively large effective area, with low mass of 30kg
- Small granularity of the scintillator array results in high angular resolution, high sensitivity for polarisation measurements



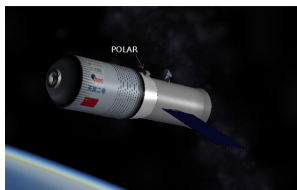
The Final Product

- Relatively large effective area
- Small pixels allows for high precision scattering angle measurements
- Uniform effective area gives us a large Field of View
- We see half of the sky and perform polarimetry for sources within 1/3rd of the sky



POLAR on the TG-2

- 2011: TG-1 Space Lab launched
- TG-2 Chinese Space Lab launch in September 2016
- POLAR launched with the TG-2
- POLAR is the only foreign payload on TG-2
- Operational time of 2 years
- Original Aim: Measuring the polarisation of upto 100 Gamma-Ray Bursts



Credit: South China Morning Po

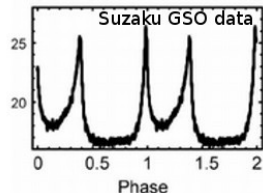
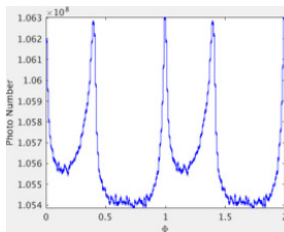
POLAR on the TG-2



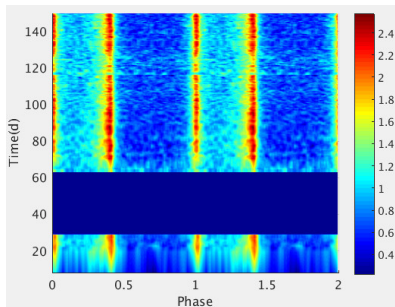
- TG-2 Chinese Space Lab launched on September 15th 2016
- Operational time of 2 years

Do we see photons?

- Crab illustrates our timing capabilities
- Crab serves as energy calibration source
- and potential polarization measurement target



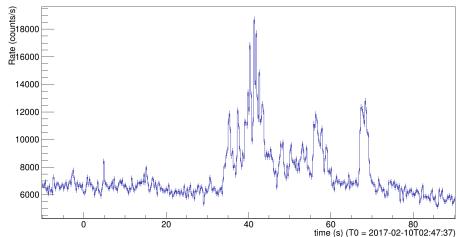
Y.Terada et al. PASoJ Dec. 2007



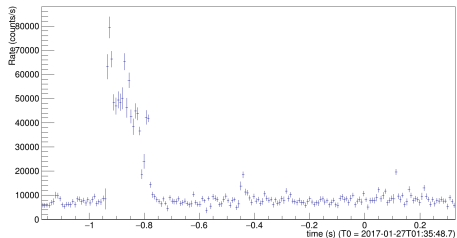
Do we see GRBs?

- Total of 49 GRBs reported to community
- Light curves on: <http://www.isdc.unige.ch/polar/lc/>
- Aprox. 10 of these GRBs have an MDP below 30%, 3 below 15%
- Detailed analysis is ongoing

POLAR-GRB 170210A (250 ms bins)

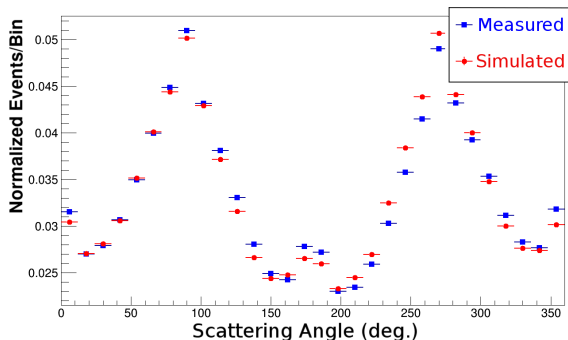


POLAR-GRB 170127C (7.8125 ms bins)



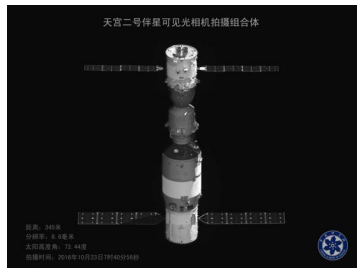
Instrument Calibration

- Careful on-ground calibration was performed
- Detailed simulations are built to reproduce the measured results in great detail
- Tests for different energies and different angles
- Paper in final stages of review correction of detection efficiency in 1600 pixels'



Summary and Outlook

- POLAR is a Compton based polarimeter designed to study GRB emission in the 50-500 keV energy range
- Instrument successfully launched
- We can see the Crab and are sensitive enough to look for exotic signals (GW, FRBs etc.)
- We have 10 GRBs from which good polarisation measurements are expected (MDP below 30%)
- Expect first polarisation results end of this year, more will follow soon after



Thank you for your attention!

