# POLAR: A Space-borne X-ray Polarimeter for Transient Sources



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POLAR:

POLAR is a novel compact X-ray polarimeter designed to measure the linear polarization of Gamma Ray Bursts (GRB) and other strong transient sources such as solar flares in the energy range 50-500 keV. A detailed measurement of the polarization from astrophysical sources will lead to a better understanding of the source geometry and to the emission mechanisms. POLAR is expected to observe every year several GRBs with a minimum detectable polarization smaller than 10%, thanks to its large modulation factor, effective area, and field of view (1/3 of the visible sky). POLAR consists of 1600 low-Z plastic scintillator bars, divided in 25 independent modular units, each read out by one flat-panel multi-anode photomultiplier. The incoming photons undergo Compton scattering in the bars and produce a modulation pattern; simulations and experiments have shown that the polarization degree and angle can be retrieved from this pattern.

### Gamma Ray Bursts (GRB): Polarization

Gamma Ray Burst are cosmic explosions that happen at random times in random places in the Universe. Polarization measurements of GRB prompt emission may distinguish between the proposed theoretical models: synchrotron with random field (the fireball model), synchrotron with ordered field (the electromagnetic model) and Compton drag (cannonball model).

## Tests with Synchrotron Radiation In December 2009 one modular unit of POLAR has been tested with 100% polarized synchrotron

radiation at ESRF in the energy range 200-500 keV. About 30M triggers have been collected. The results demonstrate the excellent polarimetric capabilities of the instrument.

### The POLAR Detector

AR is a compact detector built of 40x40 ic scintillator bars (each 6x6x200mm³), ed into 25 modular units.



- Polar characteristics: Compact (~30kg) Low power (~40W) Large eff. area (~80 cm<sup>2</sup>) Large field of view (~1/3 sky) Energy range 50-500 keV E threshold on single bar 5 keV Large modulation factor (~30-40%) Carge modulation factor (~30-40%)

**Compton Polarimetry** POLAR aims at measuring the polarization of photons that interact via Compton scattering, whose cross-section is described by the polarization dependent Klein-Nishina formula:



 $f(\xi) = K \cdot \{1 + \mu \cos[2(\xi - \xi_0) + \pi/2] + \mu^{geom} \cos[4(\xi - \xi_0^{geom})]\}$ 

where  $\eta$  and  $\xi$  are respectively the azimuth scattering angle around the photon polarization vector and around the detector x-axis,  $\mu$  is the modulation factor,  $\xi_0$  the polarization angle The second cos term is due to the square geometry of POLAR.





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Data are processed in consecutive steps: Pedestal subtraction (stability better than

2~keV over the 6 days of data-taking) • Crosstalk correction (the residual crosstalk between neighbor bars is eliminated by neglecting neighbor channels in the analysis) • Energy calibration (done via Compton edge measurements)

• Hit selection (the 2 hits corresponding to large-angle Compton scattering are selected) Total energy deposited





Uniform illumination of the detector is obtained via a scan of all 64 bars (~1.2M triggers per scan); results obtained for several polarization angles are in agreement with MC simulations.







#### Measurements with a "Polarized" Radioactive Source

Radioactive Source The e<sup>+</sup> emitted by a ~20 MBq Na-22 radio-active source annihilate in a Al target and emit two 511 keV  $\gamma$ -rays back-to back. One photon Compton scatters in a plastic scintillator (51) and interacts then via photoelectric effect in a NaI detector (TAG); the correlated photon (~60% pol.) is detected in POLAR.





**Conclusions and Outlook** 

A beam test at ESRF with 100% polarized X-rays has shown excellent performance in measurements of polarization. The engineering and qualification model of POLAR is currently under production and testing. Test beams are planned in the near future to test the whole EQM with synchrotron radiation. A flight onboard the Chinese Space Station in ~2013 is planned.

[1] N. Produit et al., "POLAR: A Compact Detector For Gamma Ray Bursts Photon Polarization Measurements", NIM A 550 (2005) 616-625

[2] E. Suarez et al., "A method to localize gamma-ray bursts using POLAR", submitted to NIM A, 2010 [3] S. Orsi et al, "Response of the Compton Polarimeter POLAR to Polarized Hard X-rays", in preparation (to be submitted to NIM A, 2010)

