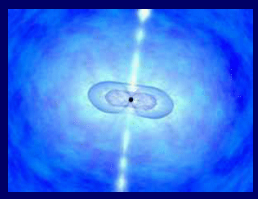
Probing Magnetic Fields during Black Hole Creation with the new γ-ray Polarimeter: POLAR

Estela Suarez-Garcia[1,3], W. Hajdas[1], A. Mtchedlishvili[1], T.J.-L. Courvoisier[2], N. Produit[2], R. Walter[2], M. Pohl[3], C. Leluc[3], D. Rapin[3], J.-P. Vialle[4], F. Barao[5], Ch. Tao[6], G. Wrochna[7], R. Marcinkowski[7]

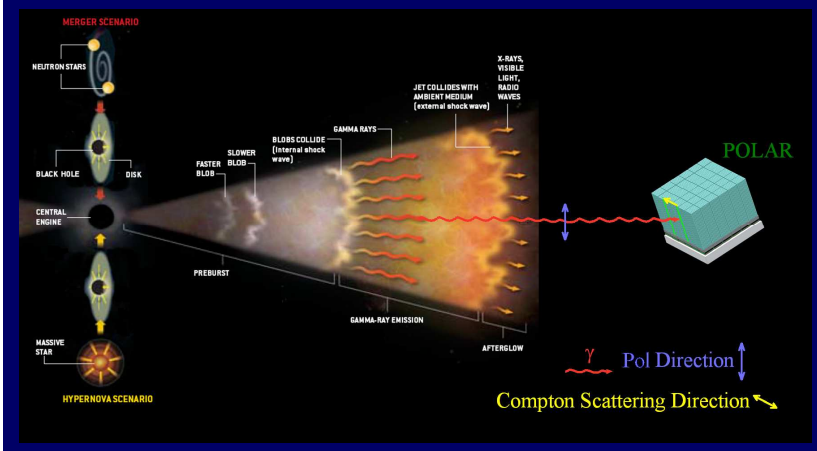
[1]*Paul Scherrer Institut (PSI, Switzerland),*
[2]*INTEGRAL Science Data Centre (ISDC, Switzerland)*
[3]*Département de physique Nucléaire et Corpusculaire, Université de Genève (DPNC, Switzerland)*
[4]*Laboratoire d'Annecy-le-Vieux de Physique des Particules (LAPP, France)*
[5]*Laboratório de Instrumentação e Física Experimental de Partículas (LIP, Portugal)*
[6]*Centre de Physique des Particules de Marseille (CPPM, France)*
[7]*The Andrzej Soltan Institute for Nuclear Studies (IPJ, Poland)*



Abstract:

The strongest explosions in the Universe, known as Gamma Ray Bursts (GRB), are associated with the creation of black holes. The magnetic field structure and dynamics during the process influence the polarization of emitted γ-rays. Thus, precise polarization detection can be a definitive tool for the determination of the true GRB emission mechanism. The data sample should contain a large number of GRBs studied with energy and time dependence. To date there have been no successful polarization measurements[1],[2] and none of the existing γ -ray detectors on satellites (Swift, Integral…) have polarization capabilities[3].

We present POLAR: a novel hard γ-ray Compton polarimeter, specially designed for studying GRB polarization[4]. It has a wide field of view, large modulation factor and large active surface. The prototype is being tested in the laboratory and the demonstration model is under construction. The Chinese Space Lab satellite and the International Space Station are candidates for the location of the experiment.



Description of POLAR

- Energy range: 5 keV – 300 keV.
- Array of 48x48 plastic scintillators (6x6x200 mm^3).
- Large field of view: 1/3 of the sky.
- Large modulation factor: 40% (at 200 keV).
- Large effective area: 450 cm^2 (at 200 keV).
- Light, fast and low Z plastic: BC400.
- No active shielding, but outer layers can be used if needed.
- Polarization calculation based on 2 largest energy depositions from Compton Scattering.

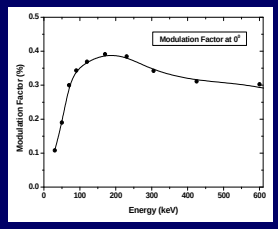
Simulations

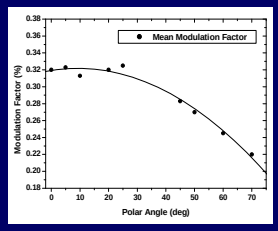
Using GEANT4 code from CERN. First set done for 2304 (4x4x200 mm^3) bars.

- Modulation factor (μ_{100}) reaches 40%.

- High plateau from 100 to 250 keV (μ_{100} > 35%).

- Modulation factor keeps almost constant for GRB up to 30° off-axis.





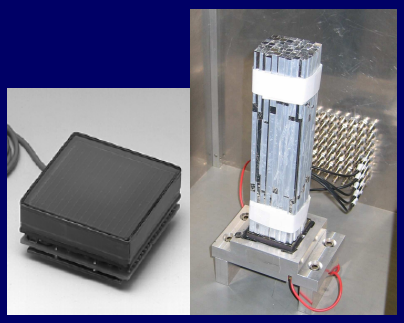
Laboratory tests

• Prototype

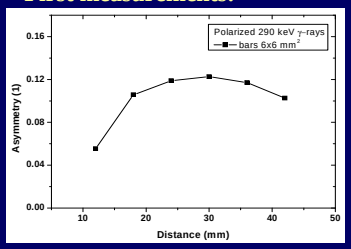
8x8 plastic bars of 6x6 mm^2 area.

H8500 Multianode Photomultiplier Hamamatsu.

The Data Acquisition System, based on an ASIC chip from GM-IDEAS, will be ready at the end of January.



• First measurements:



ASYMMETRY TESTS:

- Strong ^{137}Cs source (37 MBq).

- Simple γ-ray polarizer: photons scattered 90° on large scintillator. Trigger: triple coincidence.

- Collimated, partially polarized γ-rays ($E_{90°}$≈290 keV, P_{max}≈ 60%).

- Observed asymmetry up to 12%.

VIBRATION TESTS: Photomultiplier positively tested for vibration.

FAST TESTS: Measurement with polarized γ-rays in preparation using FAST[5] - a PSI particle physics experiment with a detector equivalent to a smaller POLAR (1536 scintillator bars, 4x4x200 mm^3).

Summary

- The Monte Carlo simulations show POLAR capabilities to measure GRB polarization (typical μ_{100} ≈ 35%, for both on- and off-axis events).
- Laboratory tests are being performed with a 8x8 prototype:
  The low energy threshold (5 keV) and the signal uniformity (95%) are confirmed. Asymmetry is found when polarized photons are used.
- Future tests:
  Mounting of a polarized source illuminating the 1536 scintillator bars array (4x4x200 mm^2) from the FAST experiment[5].
  Irradiation of the prototype with the Synchrotron Light Source.
- A proposal for financing of the full instrument has been sent to the Swiss National Found. The decision will be taken in March 2007.
- Launch with Chinese Space Agency: under the acceptance of the demonstration model in April 2007 in Beijing. POLAR would be launched in Space Lab Satellite in 2010/2011.

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[2] Suarez-Garcia, E. et al., 2006, Solar Physics, **239**: 149-172.
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[5] Casella, C., 2006. Nucl. Phys. B, **150**, 204-207.

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