GRB and Solar Flare Polarimetry with CGRO/COMPTEL

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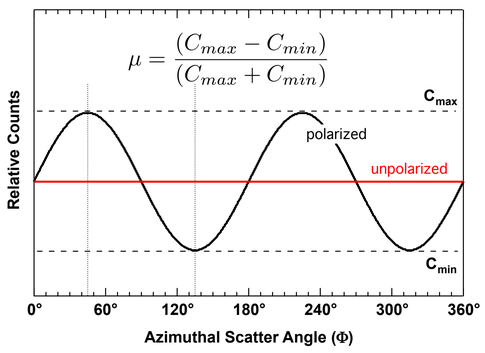
The COMPTEL instrument on the Compton Gamma Ray Observatory operated on orbit from 1991-2000. As a Compton telescope, it was intrinsically sensitive to polarization, although the geometry of the design was not optimal for polarization studies. We have embarked on a program to analyze CGRO/COMPTEL data in search for evidence of polarization in both GRBs and solar flares. We are pursuing this work because of the heightened interest in high energy polarimetry, the recognition that some high energy sources may be highly polarized (thus improving our chances of a making useful measurements), and the ready availability of modern computing resources that provide the ability to carry out more comprehensive simulations in support of the analysis. The only significant work done to date with regards to COMPTEL polarimetry was published almost 20 years ago and used a simplified mass model of COMPTEL for simulating the instrument response. Estimates of the minimum detectable polarization (MDP) near 1 MeV suggests MDP values as low as 10% for a bright GRB or solar flare. We have systematically reviewed all GRB and solar flare data collected by COMPTEL in search of candidate events suitable for a more focused analysis. The results indicate that there were insufficient statistics to measure polarization in any GRB or solar flare observed with the COMPTEL telescope mode data.

Compton Polarimetry

In Compton scattering, the incident photon tends to scatter at right angles to the incident electric field vector. For a an unpolarized flux of Compton scattered photons, the distribution of the azimuthal scatter angles (the scatter angle distribution in the plane of the detector) will be uniform. For a polarized flux of Compton scattered photons, the distribution of azimuthal scatter angles will be non-uniform and be sinusoidally distributed. This polarization signature can be used to determine the fractional polarization and the polarization angle of the incident flux. The energy-dependent *modulation factor* (μ) characterizes the polarization signature and can be used to estimate the *minimum detectable polarization* (MDP). This represents the minimum level of polarization that can be detected

Polarization Signature



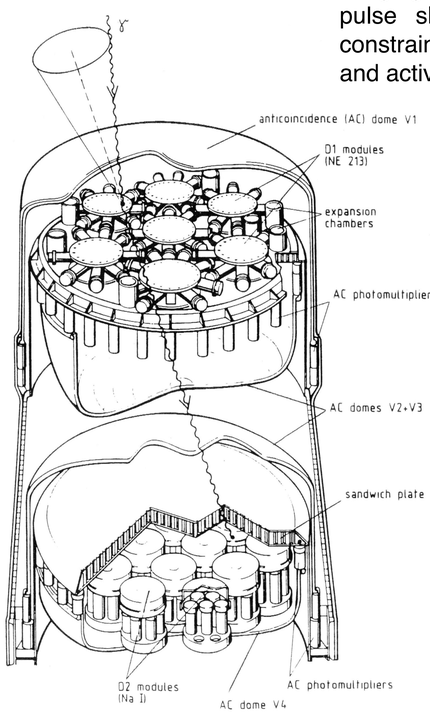
At the 99% confidence level, the MDP associated with an observation is given by,

$$MDP = \frac{4.29}{\mu_{100}\, C_{src}} \sqrt{C_{src} + C_{bgd}}$$

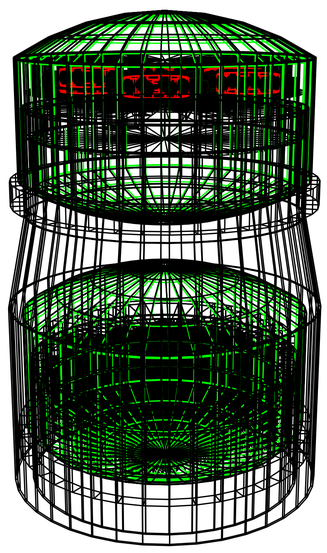
where μ_{100} is the modulation factor corresponding to fully polarized radiation, C_{src} is the total number of source counts during the observation time interval, and C_{bgd} is the total number of background counts during the observation time interval.

CGRO/COMPTEL

The COMPTEL instrument on the Compton Gamma Ray Observatory (CGRO) was a double-scatter instrument (D1 - liquid scintillator / D2 - NaI(Tl)) capable of imaging 0.75-30 MeV gamma rays. With a D1-D2 separation of 1.5 m, it relied on pulse shape discrimination (PSD), Time-of-Flight (ToF) and scatter angle constraints to identify and reject various background components (e.g., neutrons and activation of passive materials).

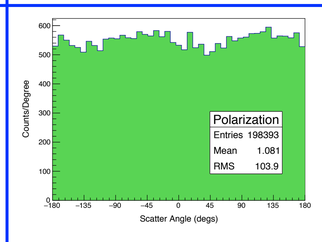
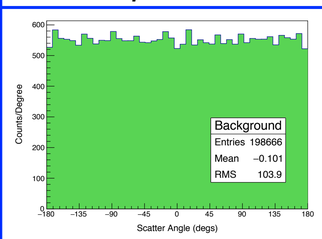
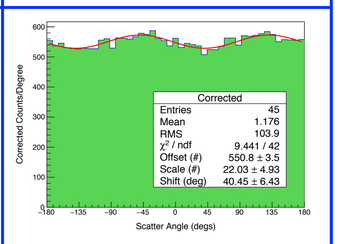
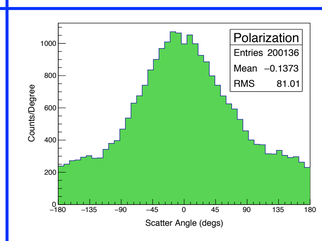
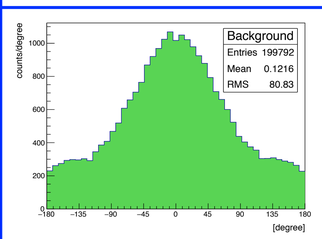
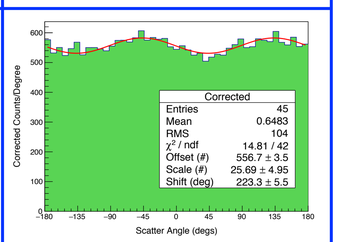
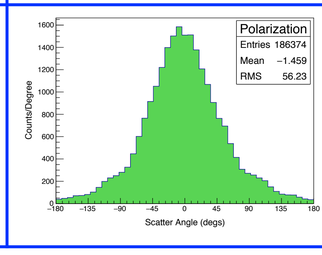
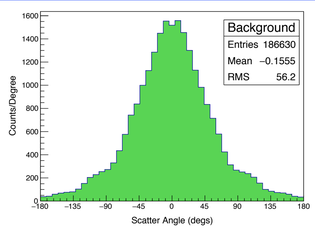
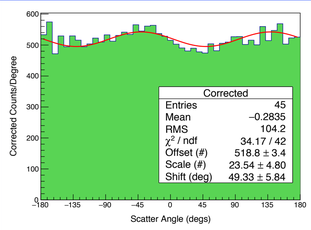


Our work employs the MEGAlib software package (Zoglauer et al. 2006, New Astronomy Reviews. 50, 629). MEGAlib provides a more user friendly interface to the GEANT4 software. One of the advantages of using this package was the ready availability of a detailed COMPTEL mass model (seen here).

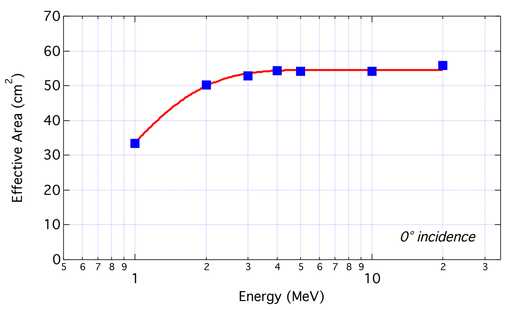


Simulation Results

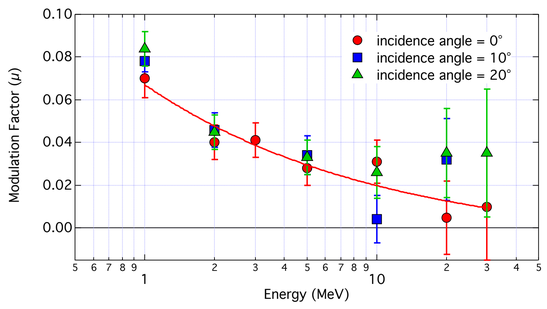
A series of mono-energetic simulations at various incidence angles have been generated using the MEGAlib software package. The azimuthal scatter angle distribution of the polarized simulation must be corrected for geometrical effects using a corresponding unpolarized simulation. Results are shown here for various cases. Geometrical effects are more pronounced for off-axis sources.

	Polarized	***Unpolarized***	***Corrected Result***
2 MeV 0° Incidence			
2 MeV 10° Incidence			
2 MeV 20° Incidence			

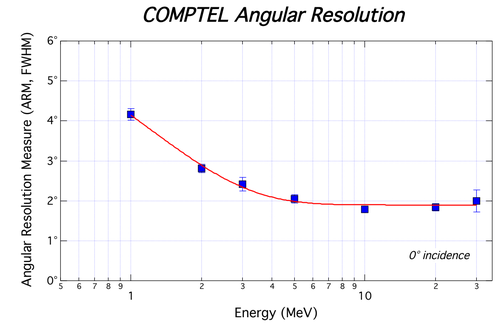
COMPTEL Effective Area



Simulated Polarization Modulation Factor



COMPTEL Angular Resolution



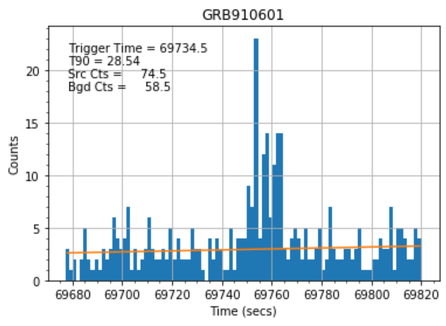
Due to its relatively poor geometry for polarimetry (favoring Compton scatter angles > 90°), COMPTEL's performance as a polarimeter is limited. Hence, the relatively small modulation factor. (Good polarimeters typically have $\mu \approx 0.5$.) However, the relatively low background (resulting in a high S/B) make COMPTEL a potentially useful tool for transient polarimetry.

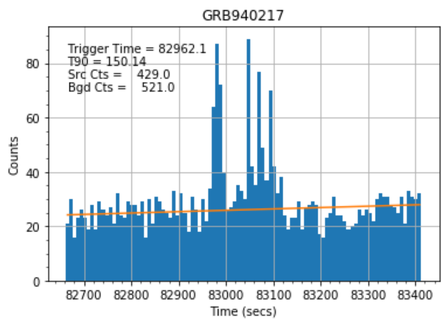
COMPTEL GRB Data

During the 9 year mission of CGRO, there were about 60 GRBs detected by COMPTEL within its FoV (within 30° of its pointing direction) using the so-called telescope mode data. The S/B is quite high for many GRBs, but the data are sometimes constrained by the limited throughput of the instrument and associated telemetry.

We have looked at all GRBs that took place within the imaging FoV of COMPTEL in order to determine the estimated MDP for each GRB. The analysis was performed over the energy range from 750 keV to 3 MeV. Several GRBs showed significant signal, two of which are shown here.

Preliminary MDP estimates indicate that none of these GRBs were measured with sufficient statistics to enable a more detailed analysis. We conclude, therefore, that CGRO was not able to measure polarization in any GRB during its nine year mission.



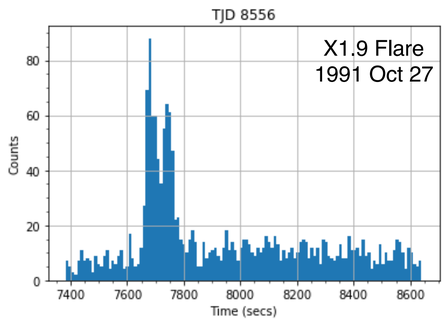


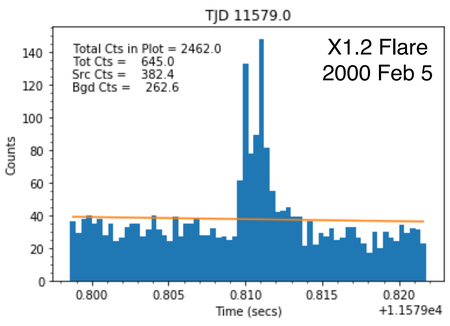
COMPTEL Solar Flare Data

During the 9 year mission of CGRO, several solar flares took place within COMPTEL's imaging FoV. In total, we looked at 6 X-class flares, 141 M-class flares, and 310 C-class flares (> C4.0) that took place within 30° of the COMPTEL pointing direction. The S/B is quite high for many of these flares, but the data are sometimes constrained by the limited throughput of the instrument and associated telemetry.

Our preliminary analysis of these flares (using a linearly extrapolated background) resulted in an estimated MDP for each flare. The analysis was performed over the energy range from 750 keV to 3 MeV. Several flares showed significant signal, two of which are shown here.

The preliminary MDP estimates indicate that none of these flares were measured with sufficient statistics to enable a more detailed analysis. We conclude, therefore, that CGRO was not able to measure polarization in any GRB during its nine year mission.





For more information, please contact Mark McConnell - Mark.McConnell@unh.edu