

# Using BATSSE to Measure Gamma-Ray Burst Polarization

M. McConnell, D. Forrest, W.T. Vestrand

*University of New Hampshire, Durham, NH*

M. Finger

*Marshall Space Flight Center, Huntsville, AL*

## Abstract

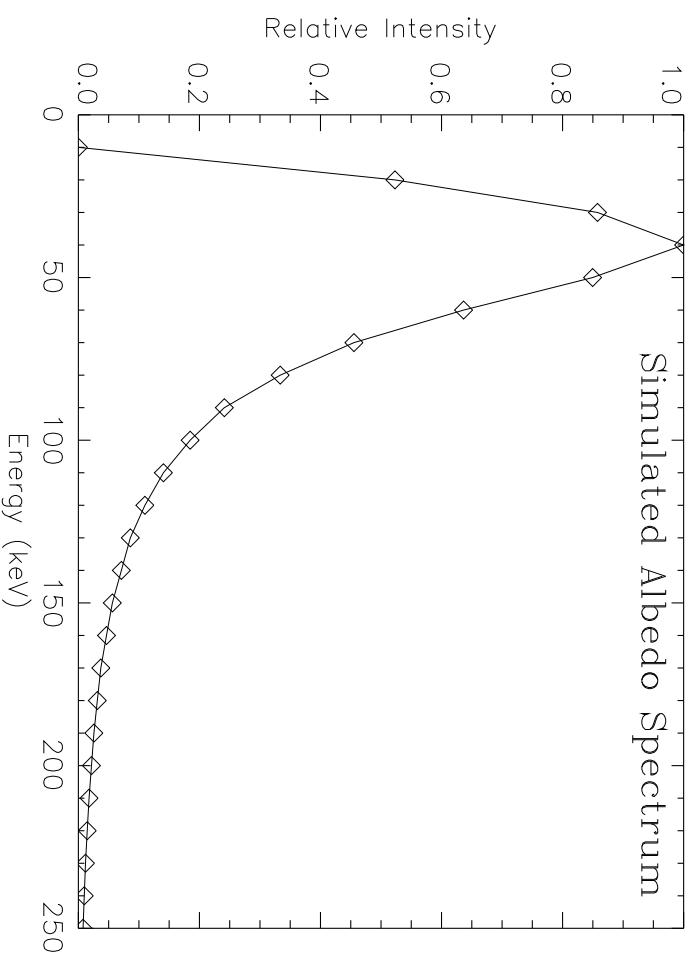
The detection of significant polarization in a  $\gamma$ -ray burst would provide an additional constraint on the plethora of models which presently exist. To date, no such measurements exist. Such measurements may be possible using a technique which we call X-ray albedo polarimetry in which the linear polarization of a  $\gamma$ -ray burst can be determined by measuring the distribution of the associated albedo flux. Due to the polarization dependence of Compton scattering, the distribution of the albedo flux depends not only on the direction of the incident flux, but also on the level of polarization and the polarization angle of the incident flux. In principle, BATSE is capable of employing this technique to measure the polarization parameters (i.e., polarization fraction and polarization angle) by making use of those detectors which are pointed towards the Earth during a  $\gamma$ -ray burst. Sensitivity estimates suggest that BATSE should be able to provide joint constraints on the polarization parameters for those events which have a 50–300 keV fluence in excess of  $\sim 10^{-5}$  ergs  $\text{cm}^{-2}$ . Here we describe the technique, its application to BATSE and the status of our efforts to measure  $\gamma$ -ray burst polarization.

## X-Ray Albedo Polarimetry

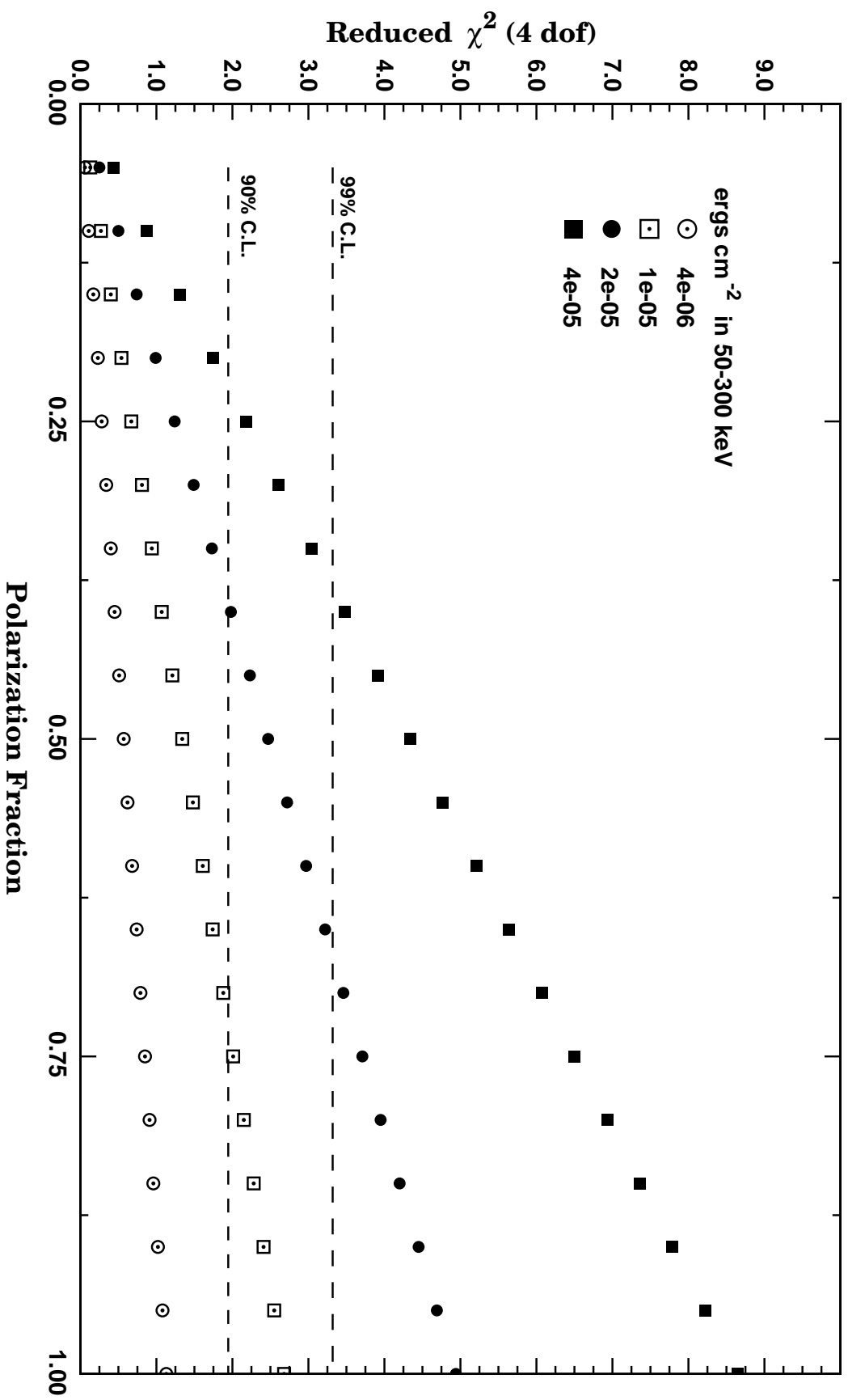
- A significant fraction of the hard X-ray flux from a celestial source (up to  $\sim 40\%$ ) is Compton reflected off the Earth's atmosphere.
- The Compton-scattered photons tend to be scattered perpendicular to the incident electric field vector.
- The angular distribution of the albedo flux will therefore depend on both the fractional polarization and the polarization angle.
- A measurement of the albedo flux can thus provide information regarding the linear polarization of the incident flux (averaged over energy, space and integration time).
- This technique affords a large effective FoV.

## Simulating the Albedo Flux Distribution

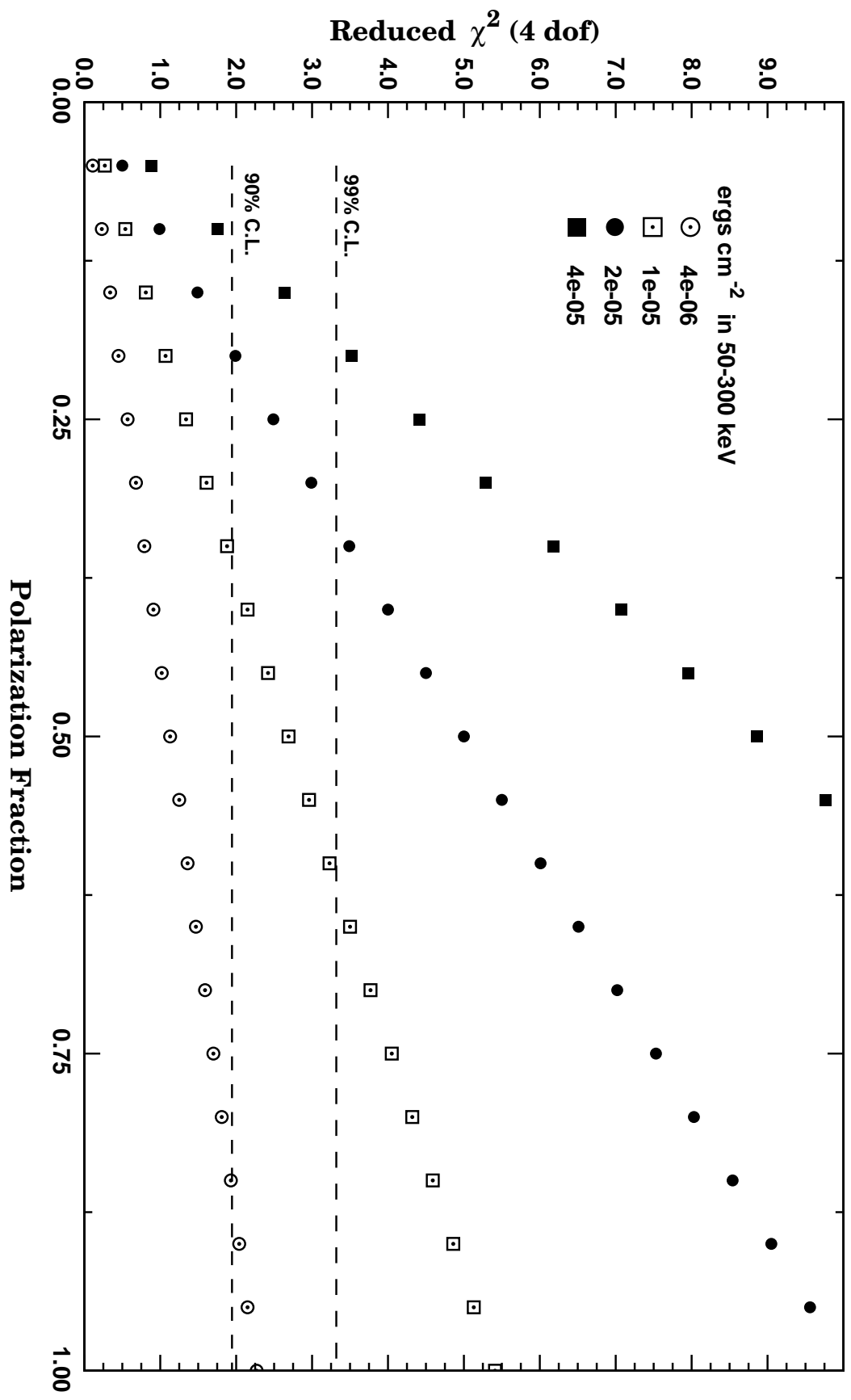
- Modified version of GEANT has been used to study the distribution of the albedo flux in the case of a linearly polarized source.
- For an incident  $E^{-2}$  power-law spectrum the albedo flux is limited to energies below  $\sim 300$  keV, with a peak near 50 keV.



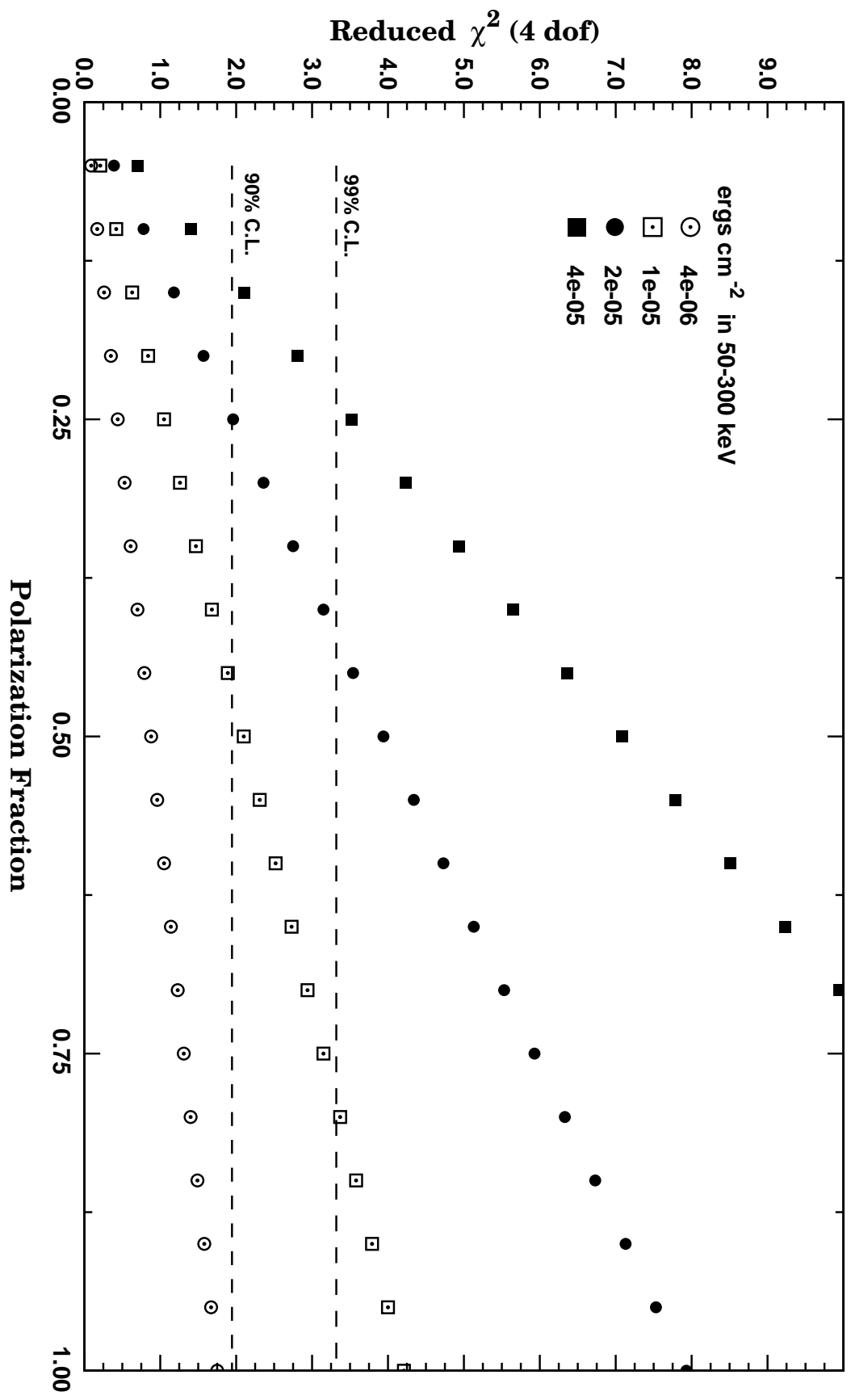
# BATSE Polarization Sensitivity : Zenith Angle = 0 degs



# BATSE Polarization Sensitivity : Zenith Angle = 30 degs



# BATSE Polarization Sensitivity : Zenith Angle = 60 degs



## BATSE Polarization Sensitivity

Although poorly designed as an albedo polarimeter, the large effective area of the BATSE LAD detectors may nonetheless permit polarization studies of the larger events.

**BATSE appears capable of setting constraints on burst polarization for bursts with fluence in excess of  $\sim 10^{-5}$  ergs  $\text{cm}^{-2}$ .**

In the BATSE 2B catalog, there are about 50 events with 50-300 keV fluence level greater than  $\sim 10^{-5}$  ergs  $\text{cm}^{-2}$ .

## Estimating the BATSE Polarization Sensitivity

- Exact sensitivity depends on:
  1. Source zenith angle ( $30^\circ$  –  $45^\circ$  appears to be optimum).
  2. Earth–Spacecraft geometry (orientation of the LADs).
  3. Incident source spectrum (shape and intensity).
- We assume an LAD angular response which falls to zero at  $90^\circ$ .
- We consider only the anti-source detectors (the direct source flux is neglected). Leakage is assumed to be zero.
- A typical BATSE background levels are assumed.
- The sensitivity is based on a comparison of the polarized versus unpolarized simulations.

## BATSE Data Analysis

- The preliminary analysis appears to be dominated by systematic effects. Several sources of systematic error have been identified :
  1. Differences in channel bandwidths amongst the LAD detectors.
  2. Deadtime effects.
  3. Leakage of incident source flux through the spacecraft.
  4. Need to account for precise form of incident spectrum.
- On-going analysis will account for these systematic effects and will include data from all eight LAD detectors (incorporating the response to direct flux).

## Summary

- X-ray albedo polarimetry is a potentially useful technique for studying the polarization (i.e., directivity) in  $\gamma$ -ray bursts at hard X-ray energies.
- Sensitivity estimates indicate that polarization levels  $< 10\%$  may be achievable for more intense  $\gamma$ -ray bursts.
- Preliminary analysis efforts are dominated by systematic effects, several of which have been identified, but not yet properly accounted for in the analysis.