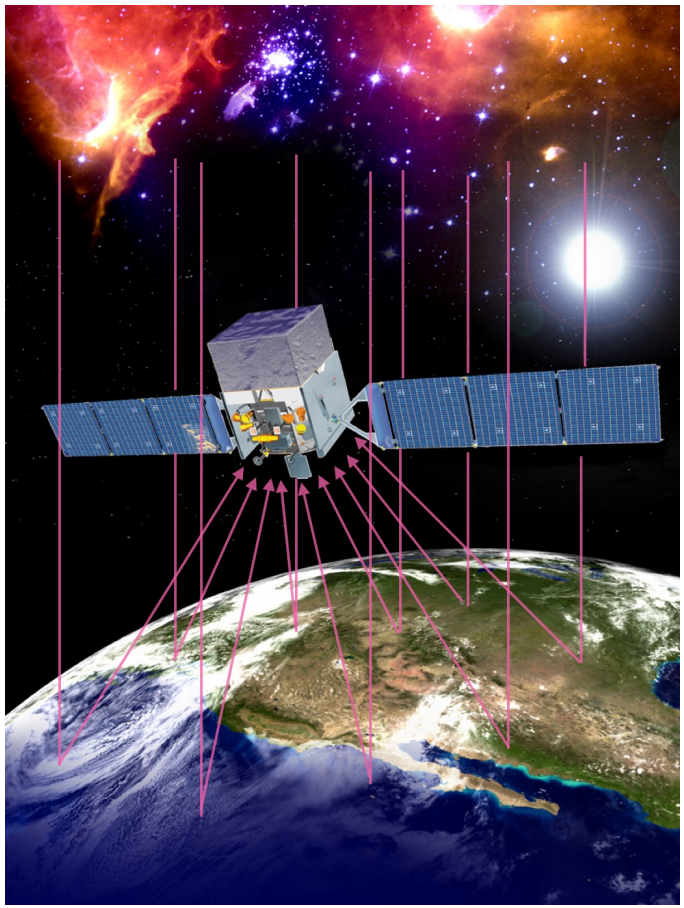
Fermi Gamma-ray Burst Monitor as a ***Polarimeter***

Fermi Symposium 2024

Peter Veres (University of Alabama in Huntsville)

Wade S. Duvall (Naval Research Lab)
Adam Goldstein (Universities Space Research Association)
Michael S. Briggs (University of Alabama in Huntsville)
J. Eric Grove (Naval Research Lab)

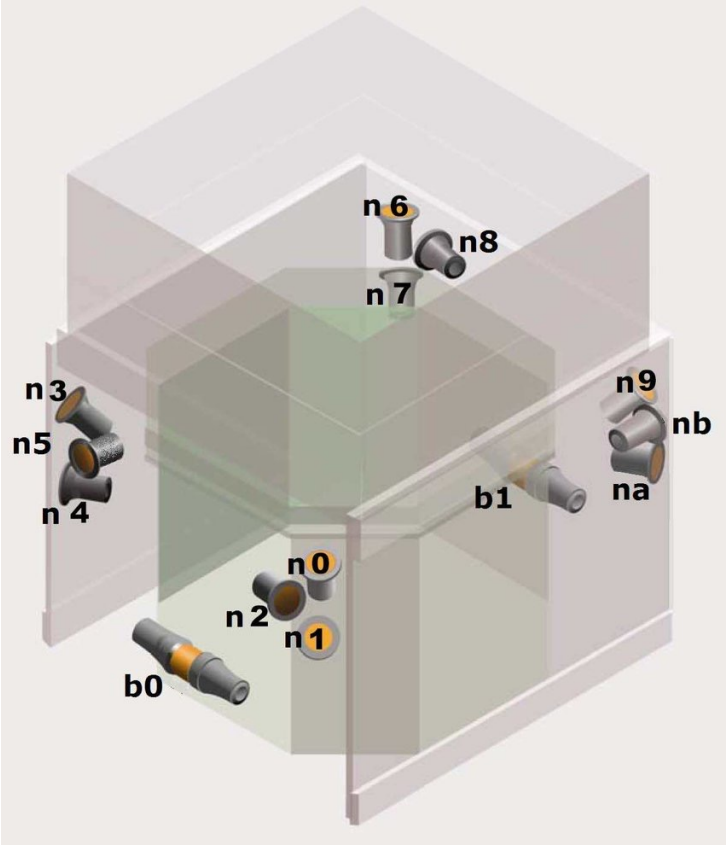


Details: arXiv:2408.13199

Motivation for polarimetry- Fermi GBM

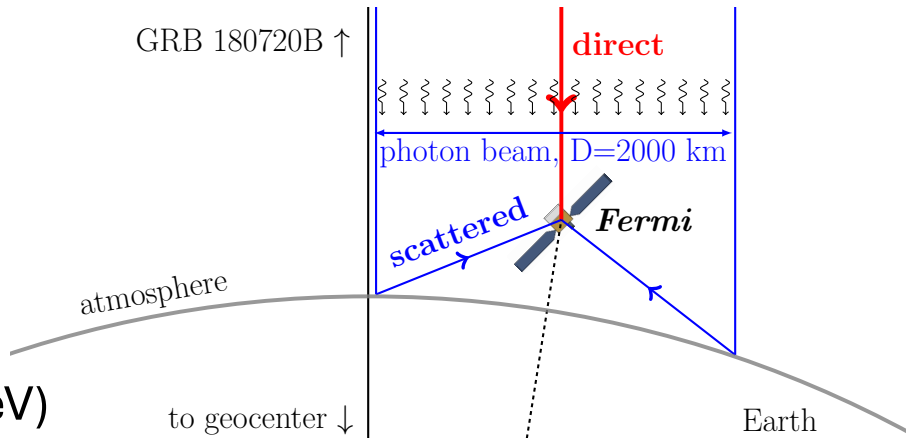
- GRB polarimetry is difficult:
  - Contradicting results in the literature
  - Pin down jet composition, geometry, emission mechanism
- Future (2027+): COSI, Polar-2, Daksha
- While we wait… GBM:
- ~535 km altitude, ~96-minute orbit
- 12 NaI detectors (8 keV – 1 MeV) – pointing in different directions
- Some detectors point close to the atmosphere: TGFs

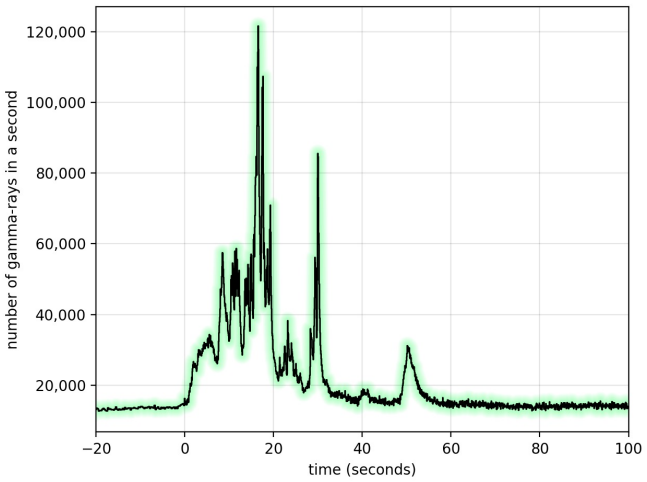
- *GBM not designed as a polarimeter*

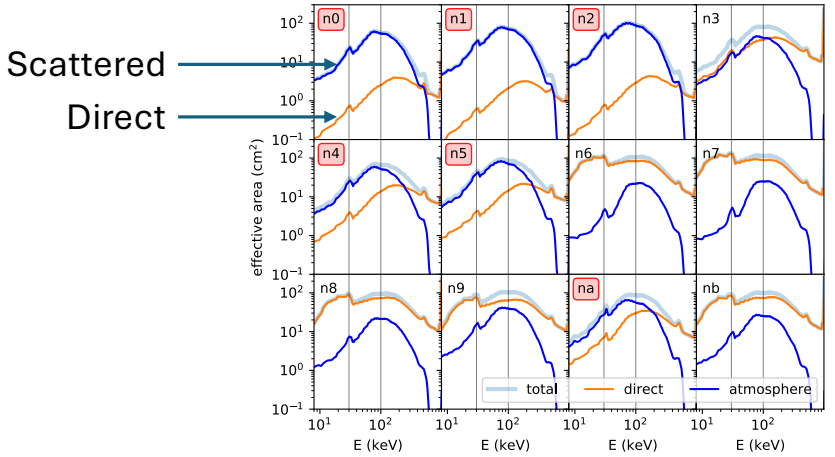


Setup

- Need GRB close to Fermi zenith
  - **GRB 180720B** (zenith angle = 9 deg)
  - Very bright GRB – also detected at VHE by H.E.S.S. (Abdalla et al., 2019)
- Direct and scattered photons
- Some det's: scatt. photons dominate (30-100 keV)
- Atmo. sim. in SWORD software, developed at NRL

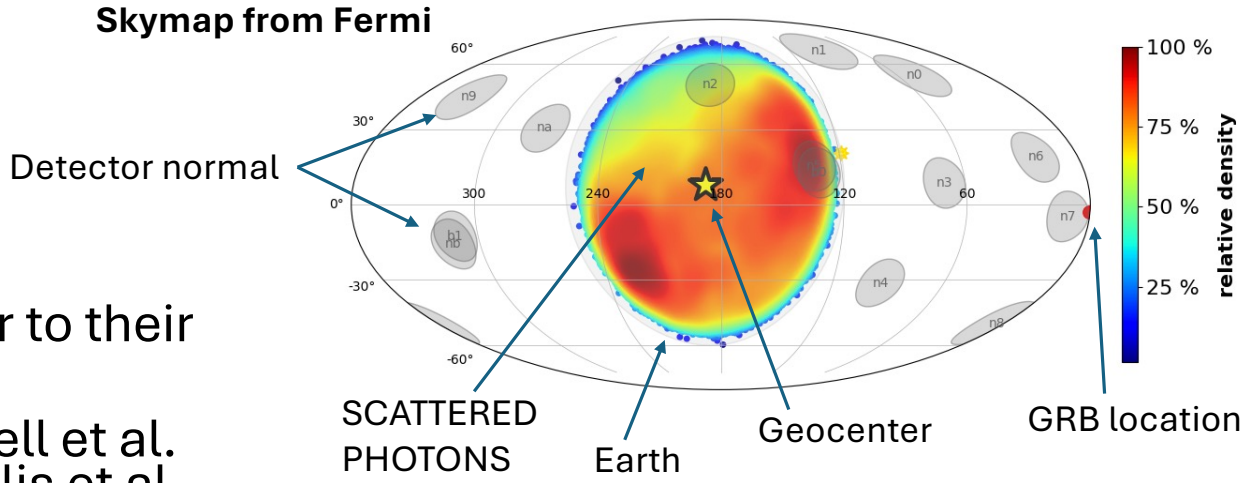


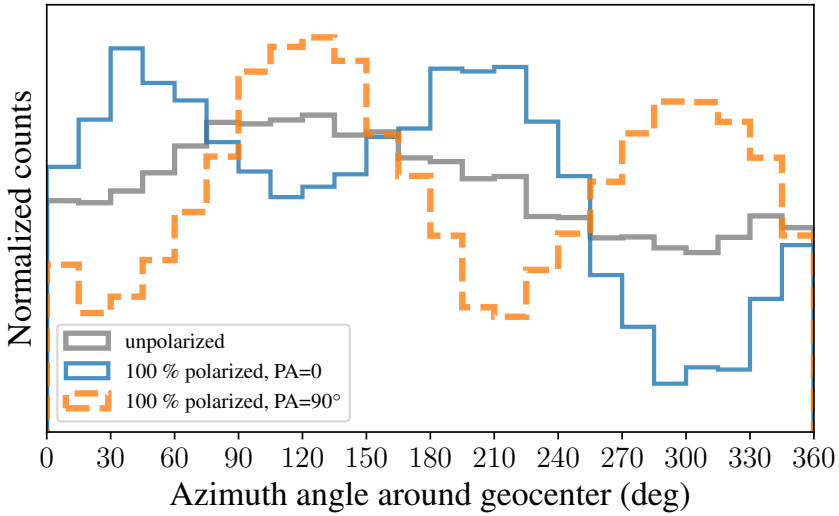




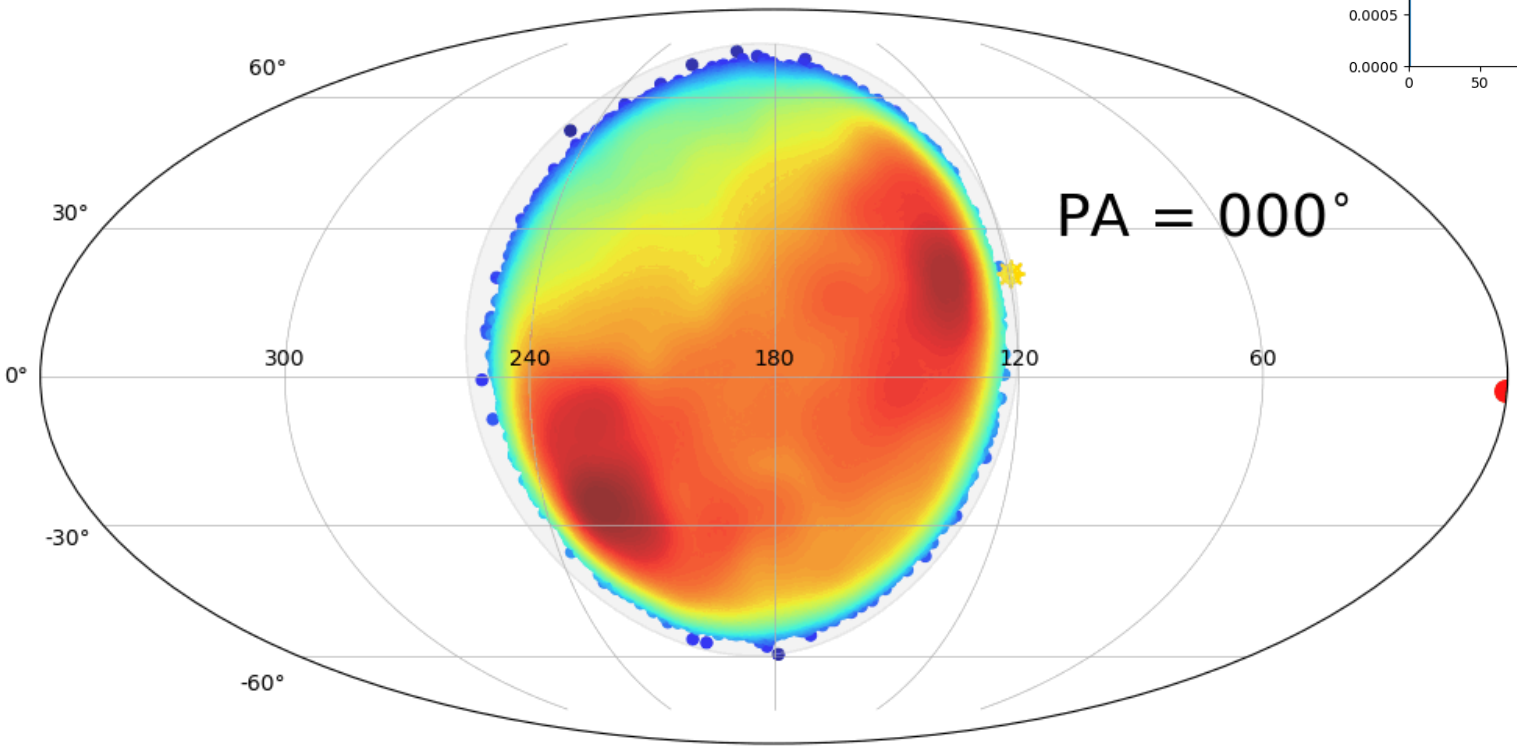
Method

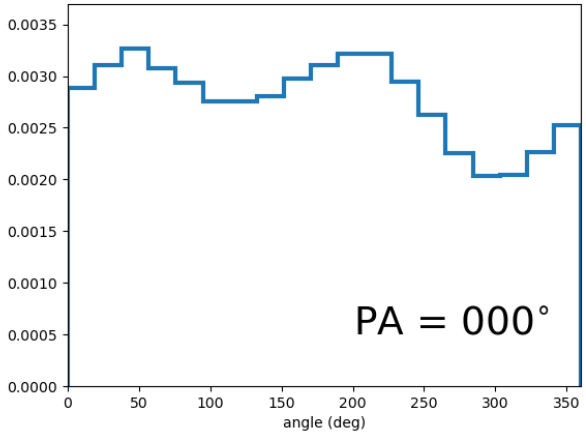
- Polarized photons scatter preferentially perpendicular to their electric field vector
- First suggested by McConnell et al. 1996, applied to BATSE: Willis et al. 2005.
- When polarized photons scatter off the atmosphere, they imprint a pattern that is different from unpolarized photons.
- GOAL: identifty this pattern in the GBM detectors - match to observations





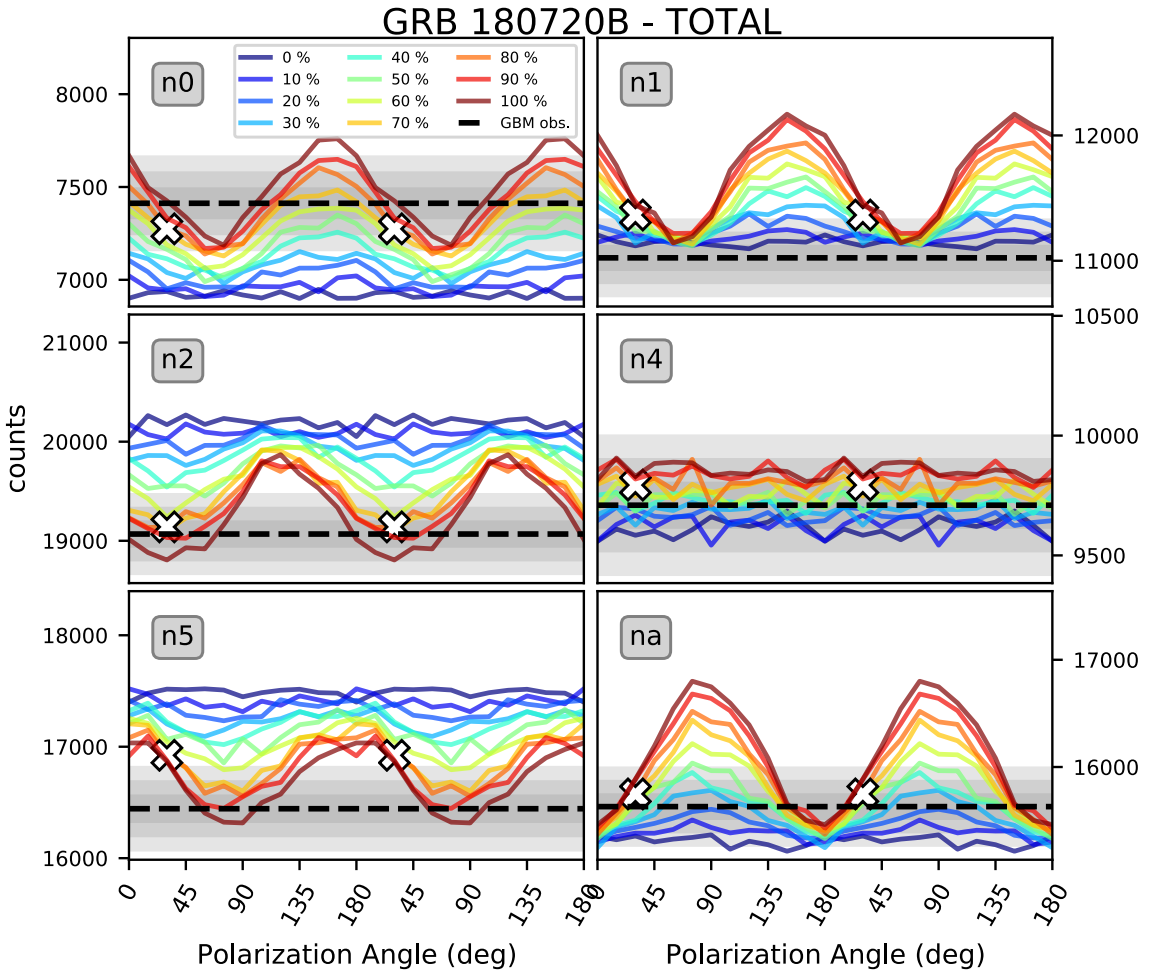
Scattering pattern for 100% polarized gamma-rays





Simulations

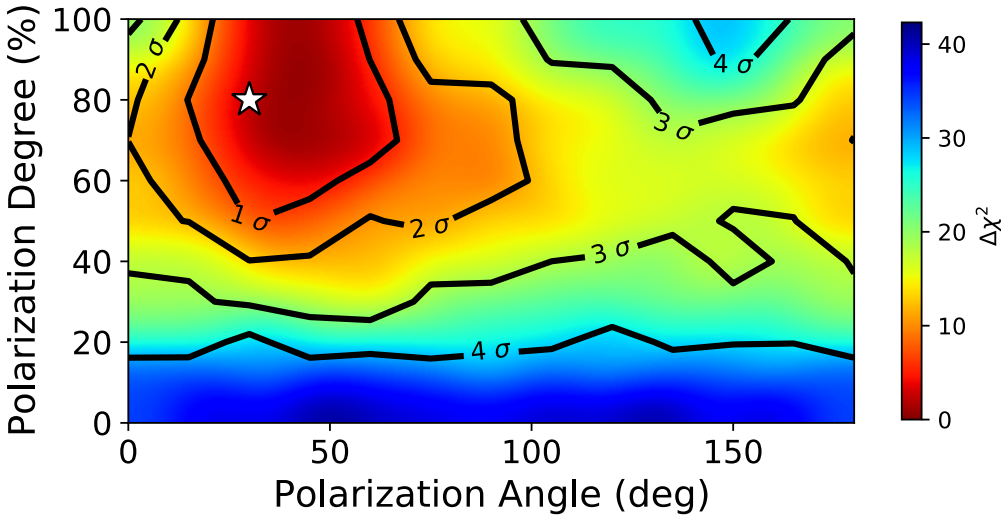
- Direct & scattered photons
- Simulate
  - PD=0 ..100%, steps of 10
  - PA=0 .. 180 deg, steps of 15 deg
- Convolve with detector response (direct & scan atmo.)
- Normalize
- Compare sim. with observed counts
- Find minimum displacement, (PA, PD) for good detectors



Results

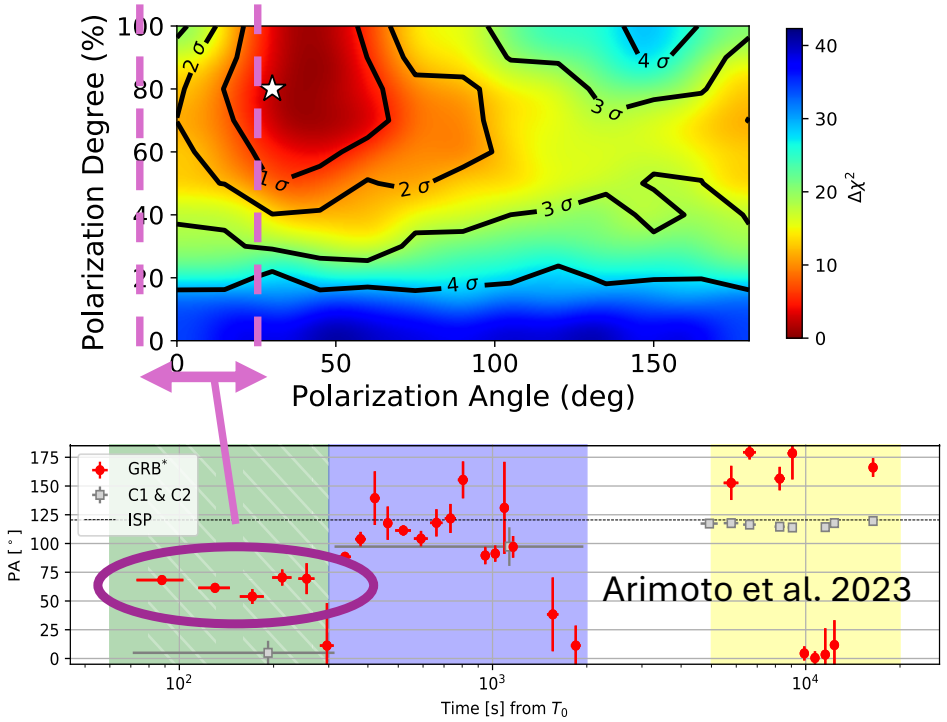
- Found non-zero polarization
- Peak: (PA, PD) = (30 deg, 80%)
- PA = 35^{+11}_{-9} deg
- PD = 72^{+24}_{-30} %

- Systematics – assumed 50% of statistical
- 5 detectors used (2 BATSE det. in Willis et al. 2005)



Confirmation(?), interpretation, outlook

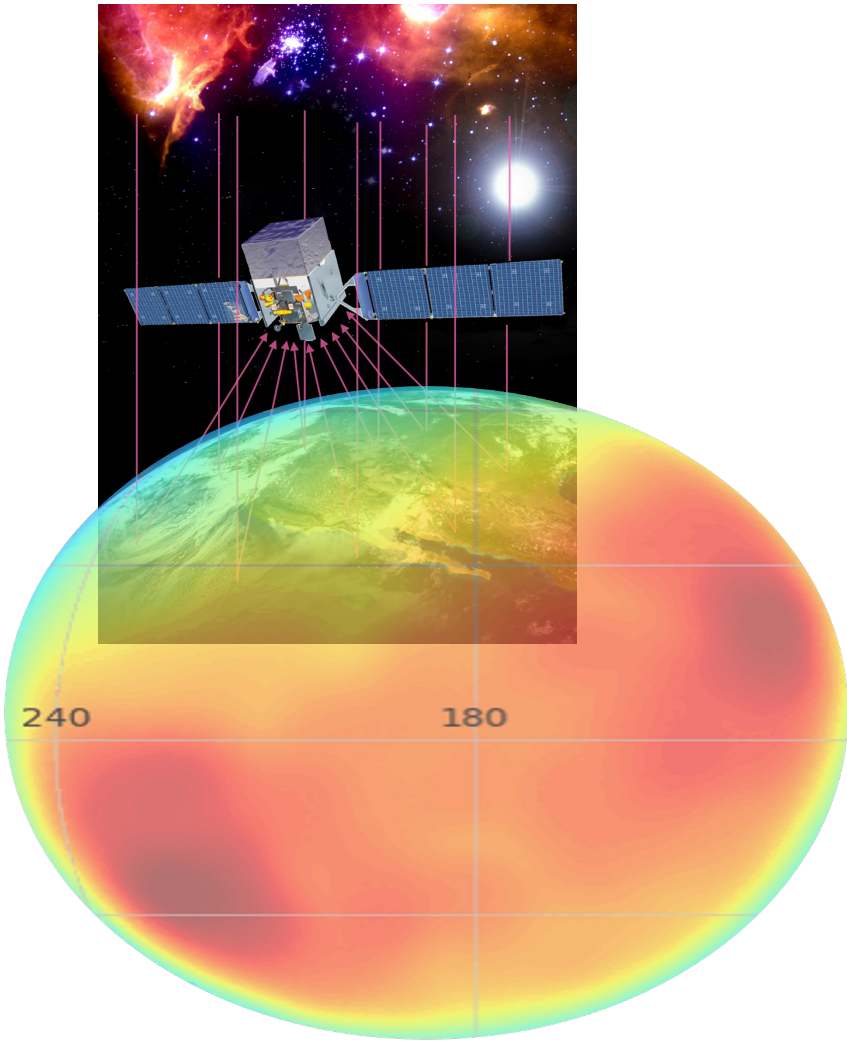
- Kanata telescope measurement:
  - **PA ~consistent**
  - Arimoto et al. 2023
  - PA=50-80 deg (eq. frame)
  - T>70 s (rev. sh?)
  - This work: T<56 s
- High polarization suggests synchrotron + ordered **B** field
- Other GRBs:
  - High flux, low zenith angle
  - Tens of GRBs in GBM
  - Need dedicated analysis



Conclusions

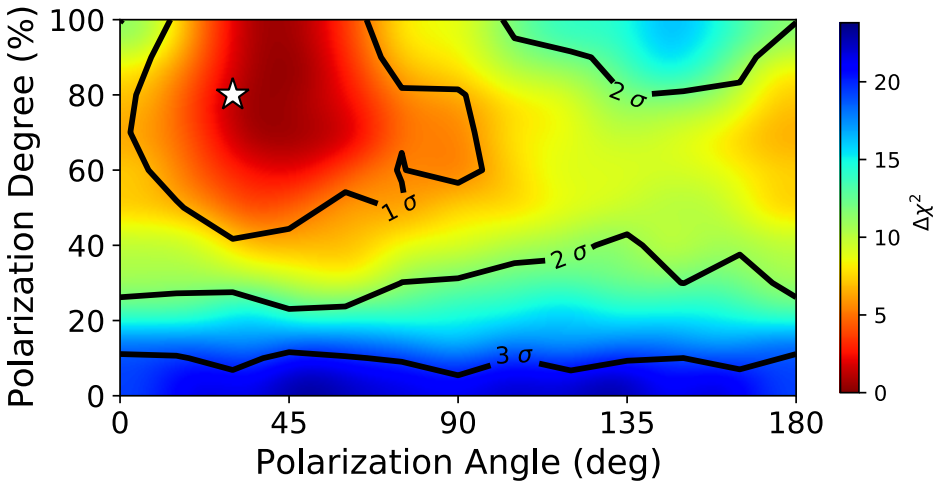
- GBM can be used as a GRB polarimeter
- Found high polarization degree (72^{+24}_{-30} %)
- PA compatible with optical obs.
  - Caveat: systematics
- More good candidates to check

Details: arXiv:2408.13199



Extra material

Systematics: 100%



Selection of GRBs