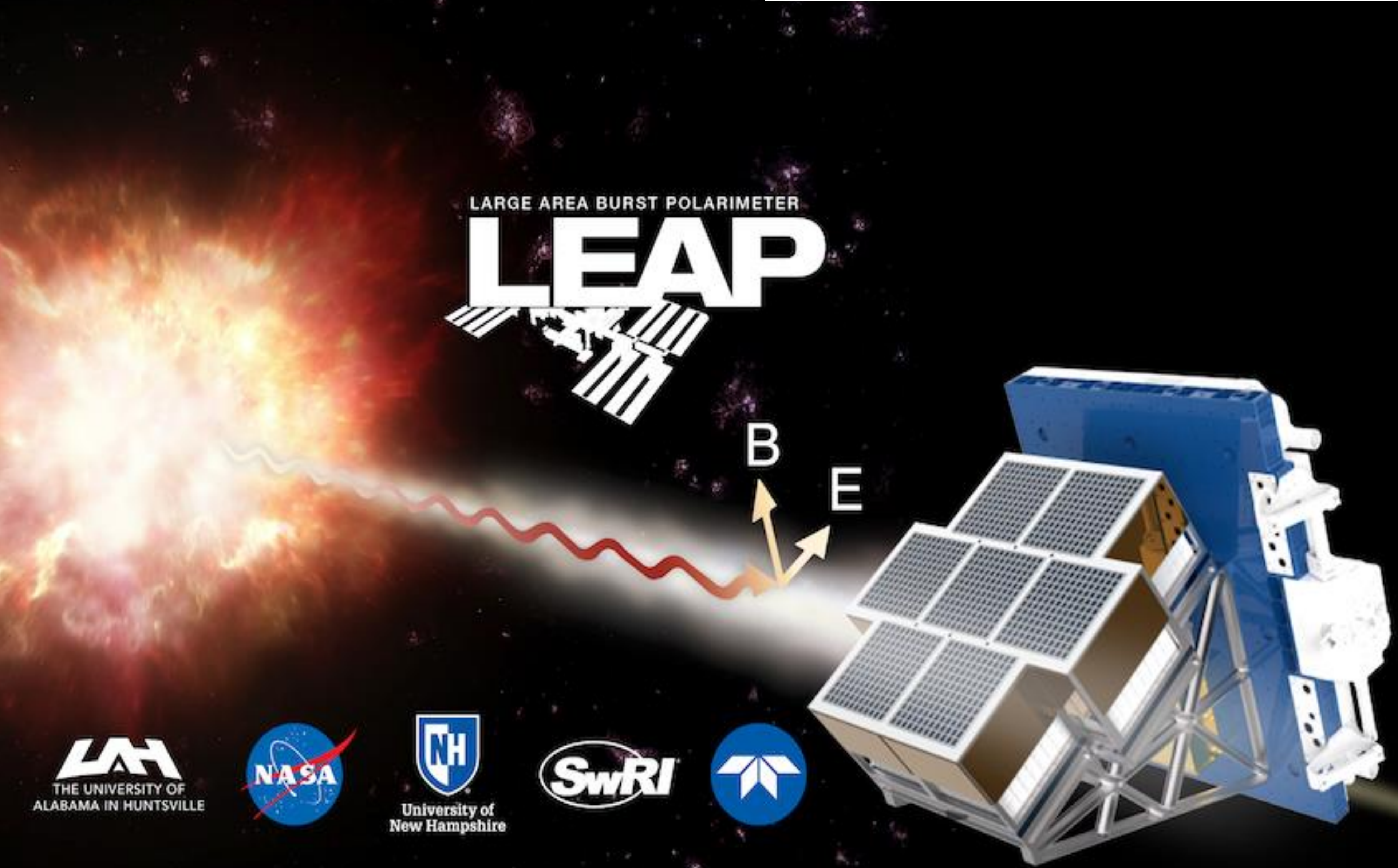
LARGE AREA BURST POLARIMETER
LEAP



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NASA

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SwRI

Colleen Wilson-Hodge (NASA/MSFC)
on behalf of the LEAP collaboration

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LEAP will Tell Us About...

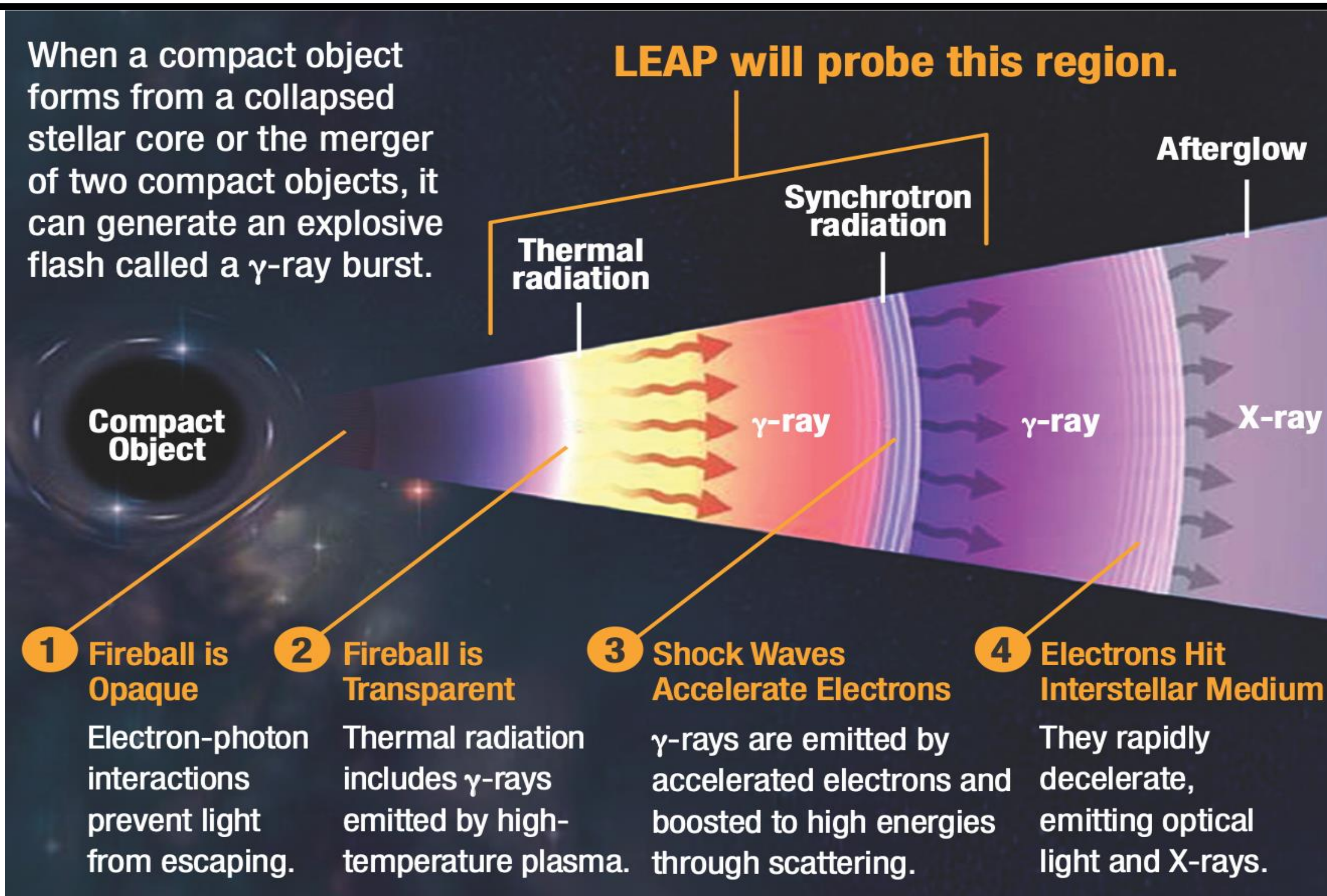
1 – JET COMPOSITION
Is the jet dominated by matter or radiation?

2 – JET MAGNETIC FIELD STRUCTURE
Are the magnetic fields oriented at random or do they have an ordered structure?

3 – JET ENERGY DISSIPATION PROCESS
Is the jet energy dissipated through internal shocks or reconnection?

4 – PROMPT EMISSION MECHANISM
What roles do synchrotron, inverse Compton, and thermal emission play?

Anatomy of a Gamma-Ray Burst



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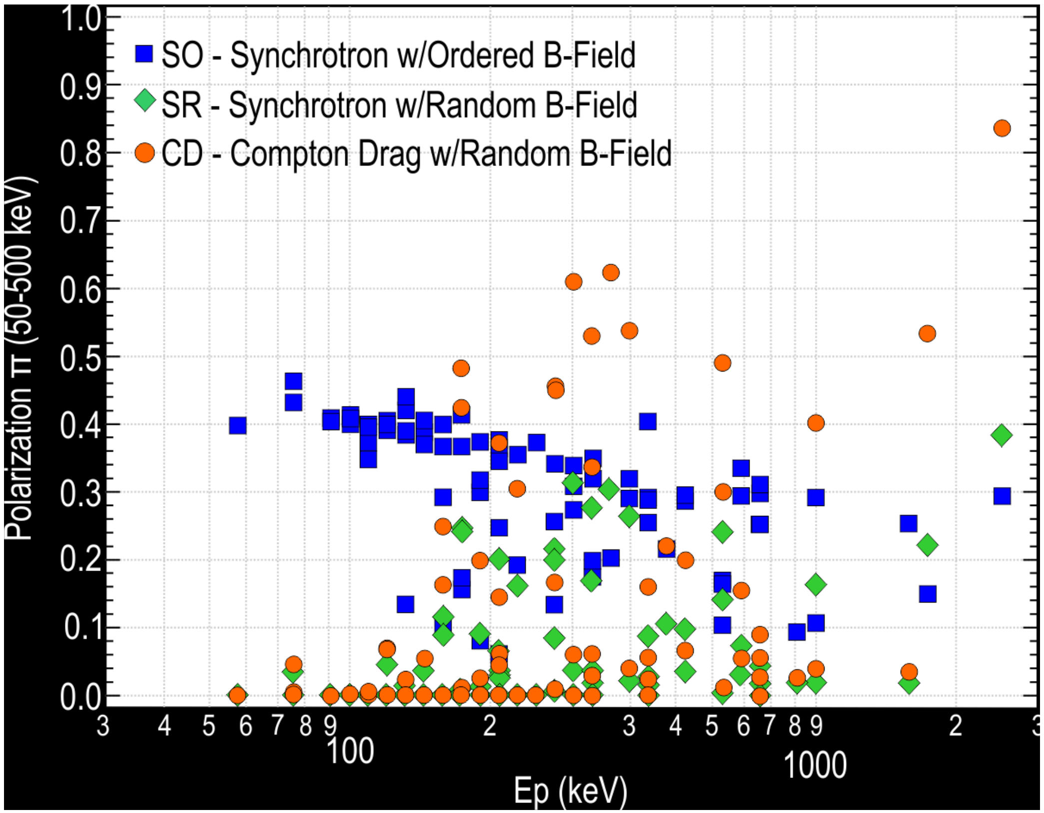
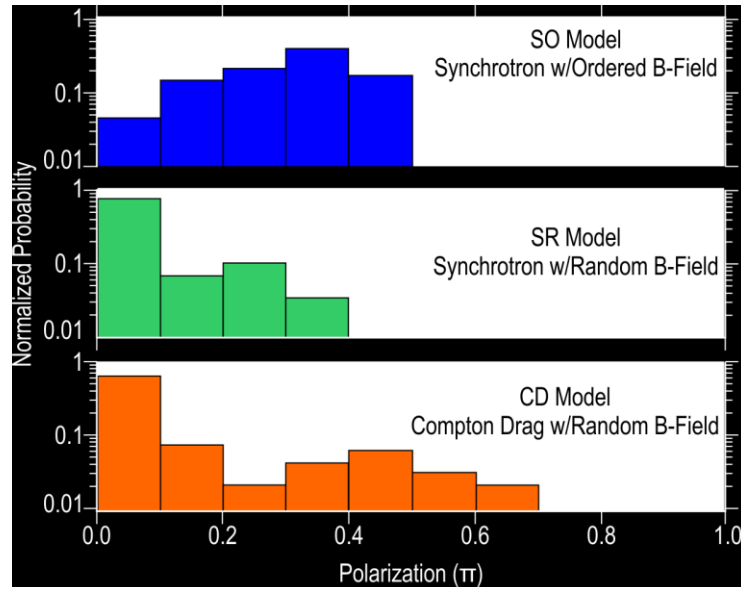
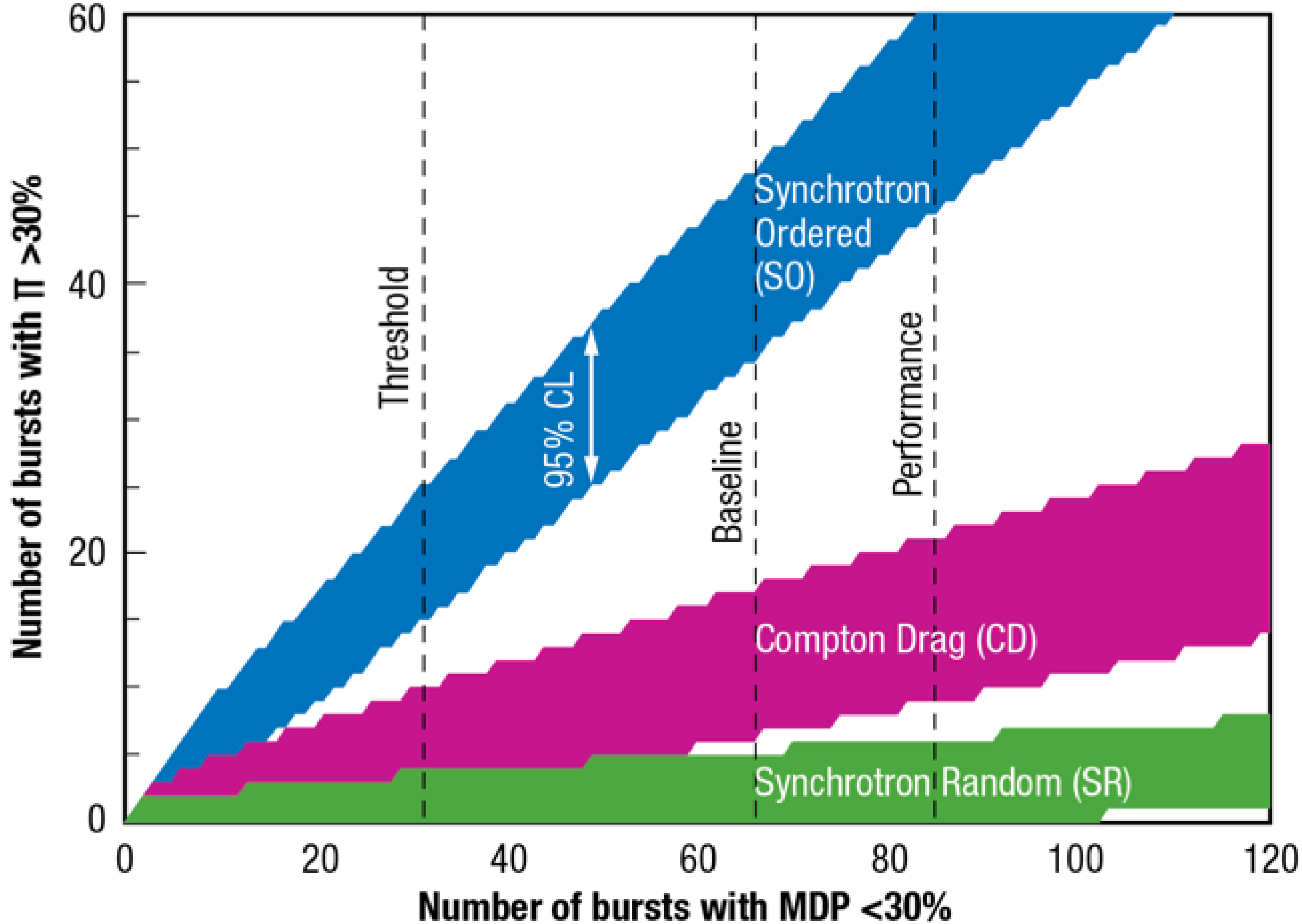
Polarization Distributions

Toma et al., ApJ, 698, 1042 (2009)



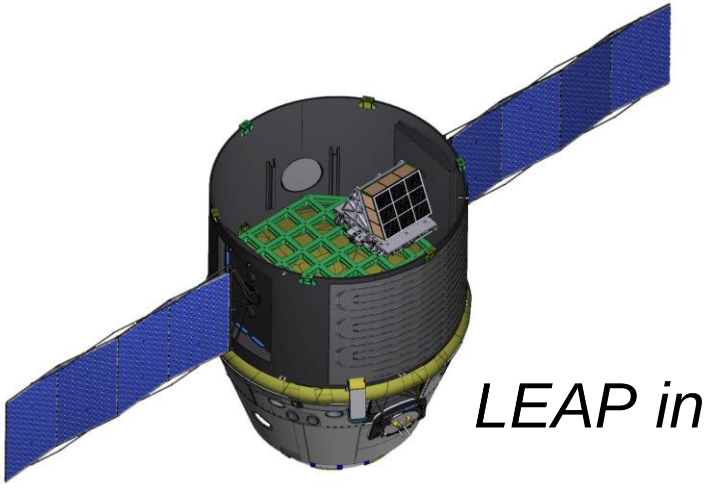


Polarization Distributions



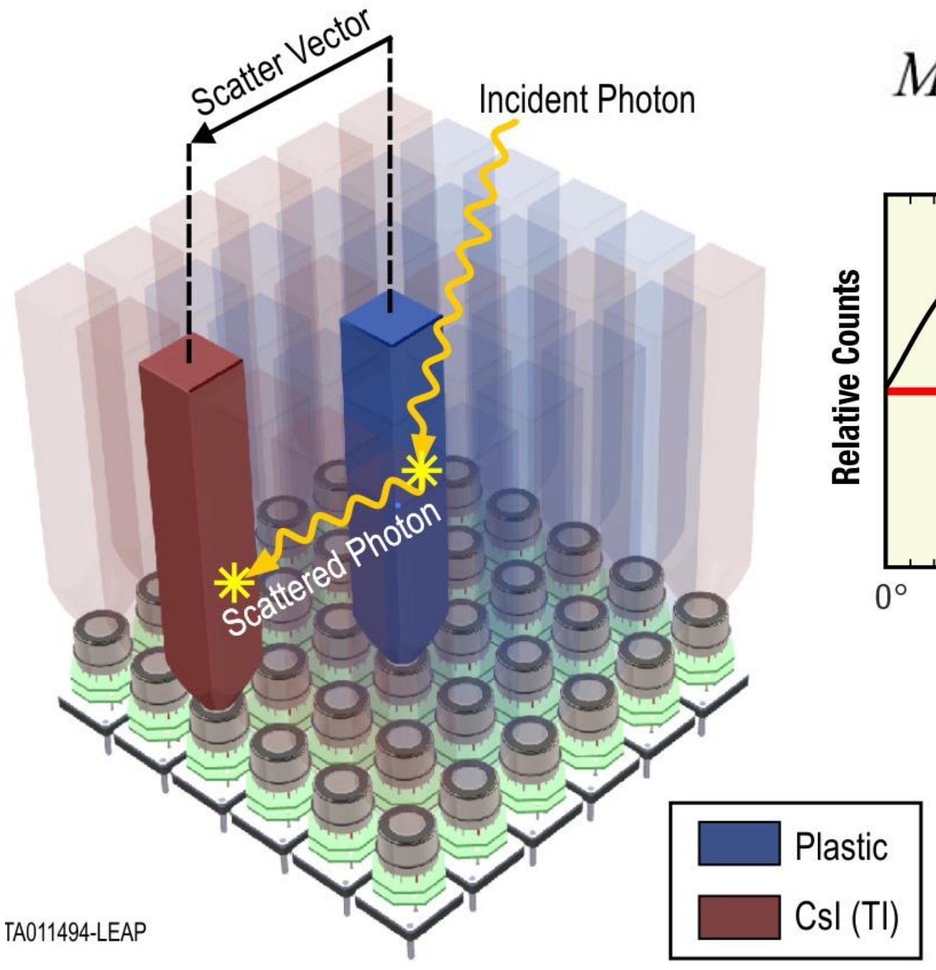
What is LEAP?

- NASA Mission of Opportunity Selected for Phase A study
- Large-Area, Wide-FoV Compton Polarimeter
- 50-500 keV polarimetry
- 20 keV - 5 MeV spectroscopy
- Externally attached to ISS
- Launch date ~2025
- Minimum 2.5 year mission

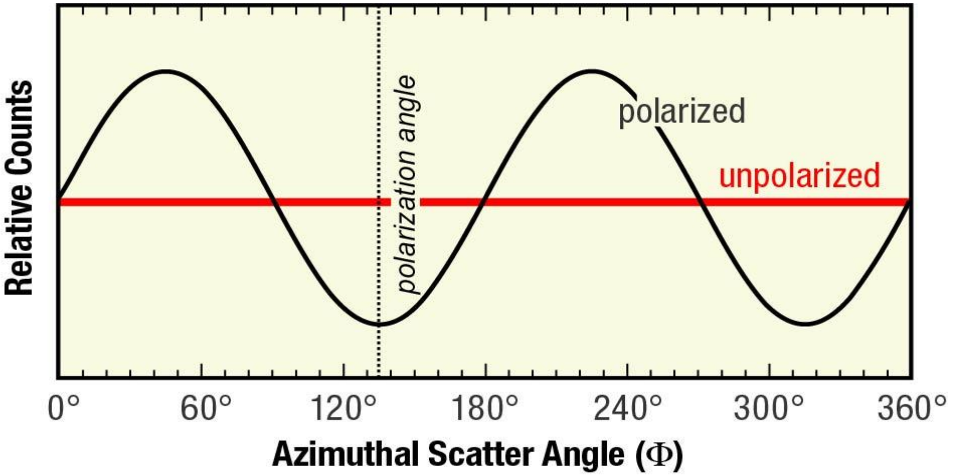


LEAP in Dragon trunk

LEAP is a Compton Polarimeter



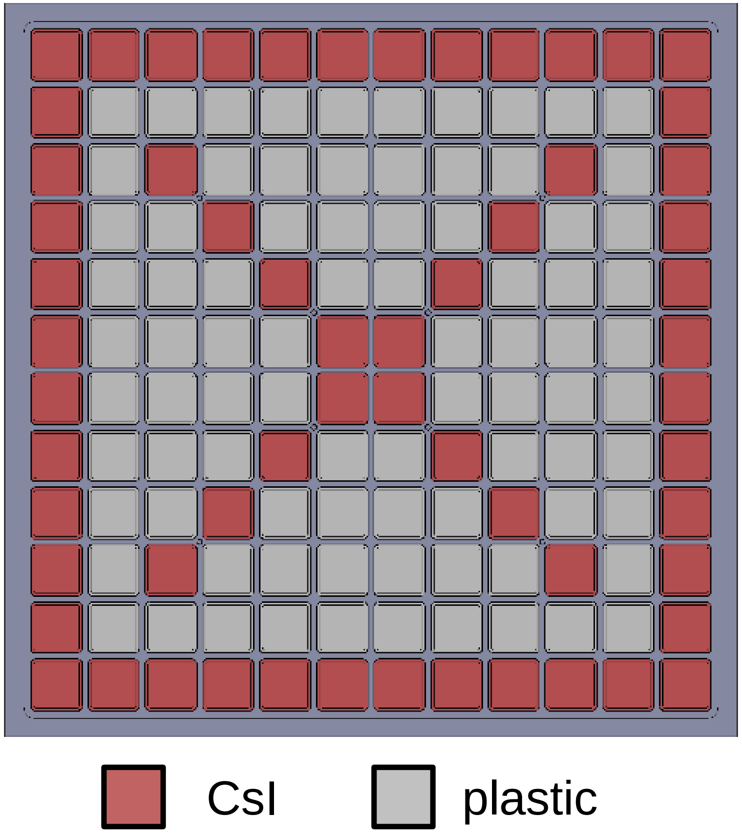
$$MDP = \frac{4.29}{\mu_{100} F_S A_{eff}} \left(\frac{F_S A_{eff} + R_B}{t} \right)^{1/2}$$

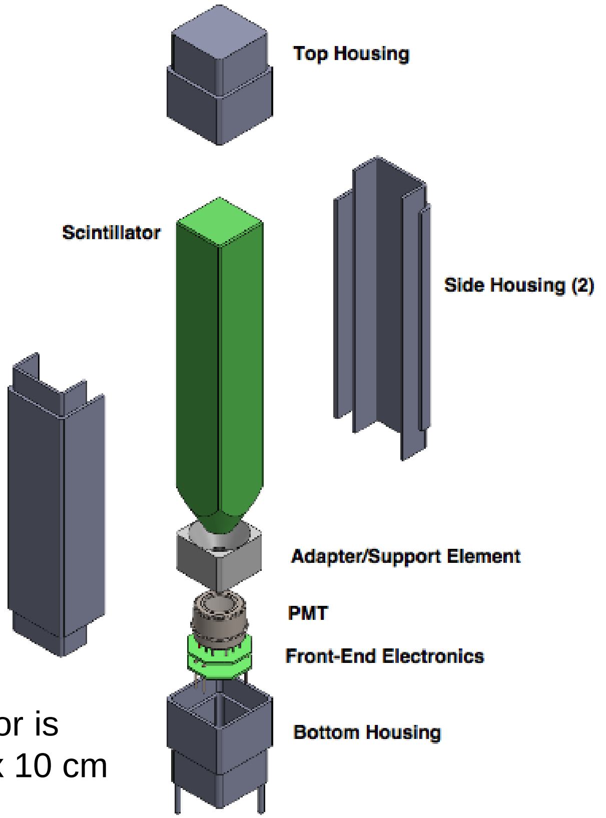


The LEAP instrument design is based on GRAPE balloon payload developed at UNH.

LEAP Scintillator Geometry

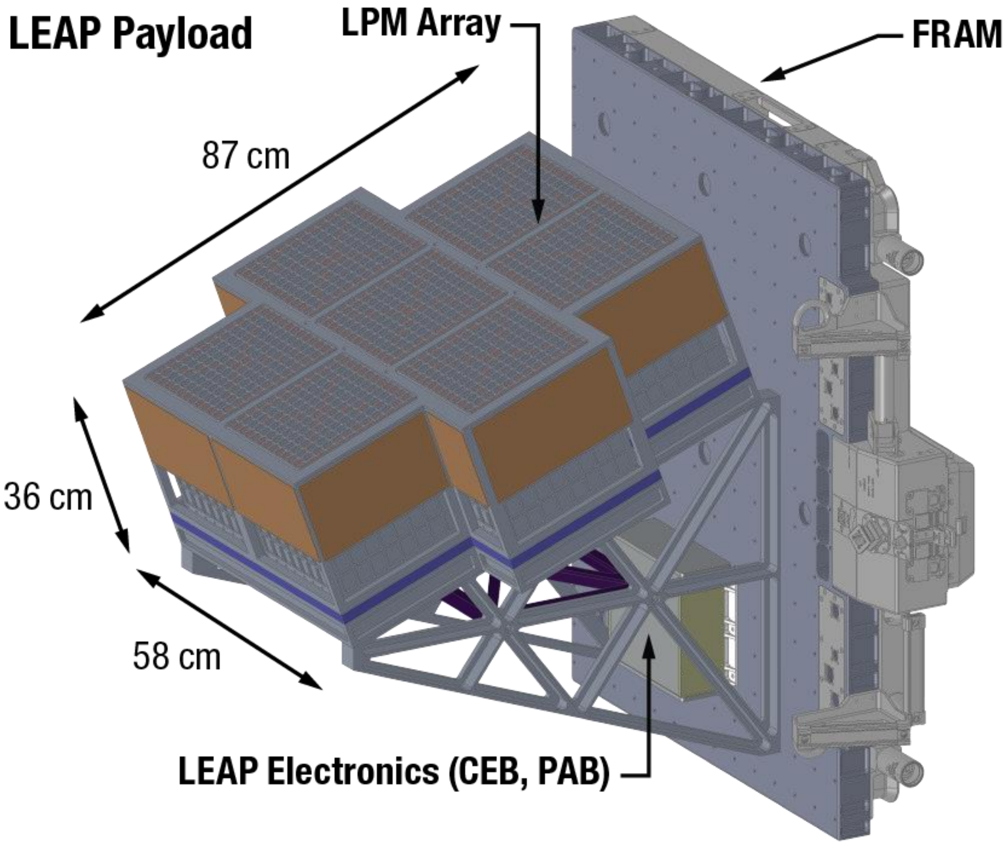
A single module consists of 144 discrete detector elements



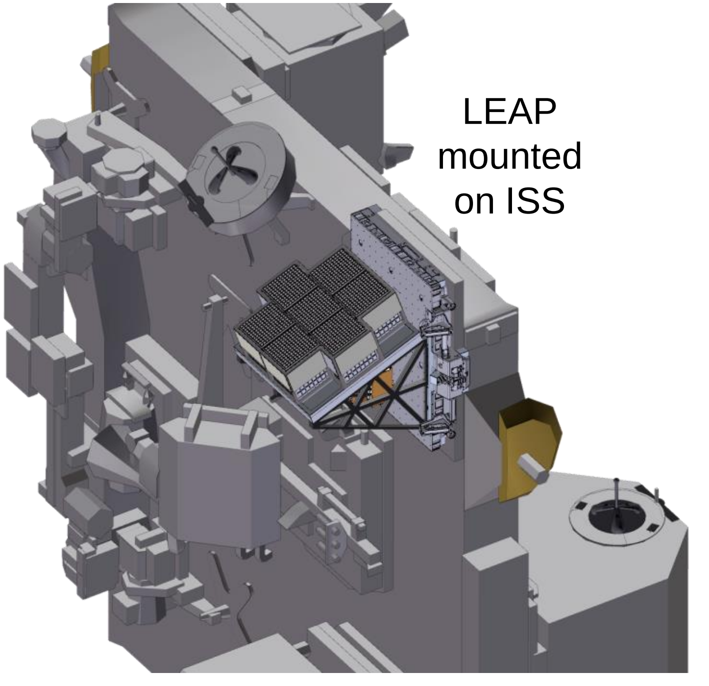


Each scintillator is
1.7 cm x 1.7 cm x 10 cm

LEAP Polarimeter Array

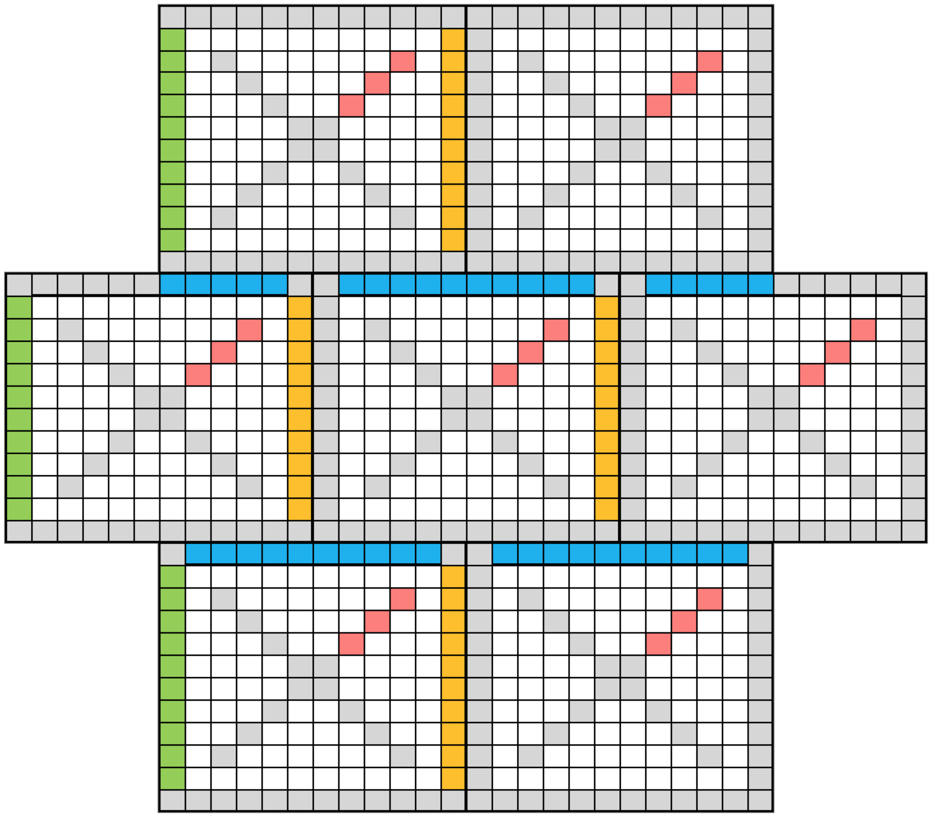


Full LEAP instrument consists of 7 independent polarimeter modules surrounded by passive Pb shielding on sides and bottom.

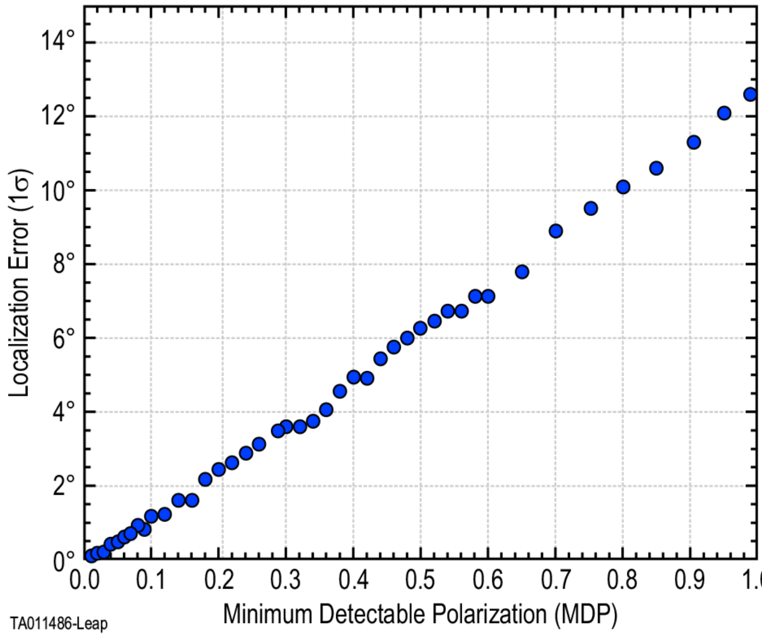


LEAP GRB Localization

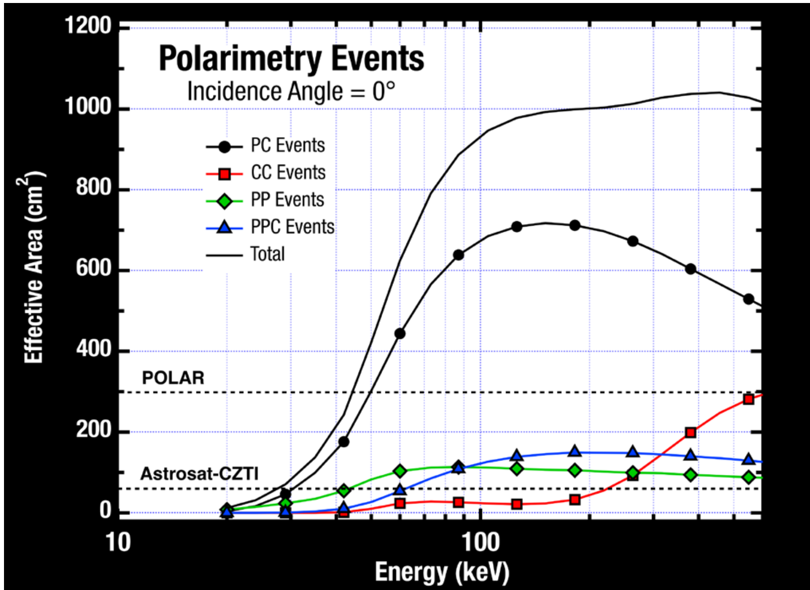
LEAP uses virtual detector groups for localization

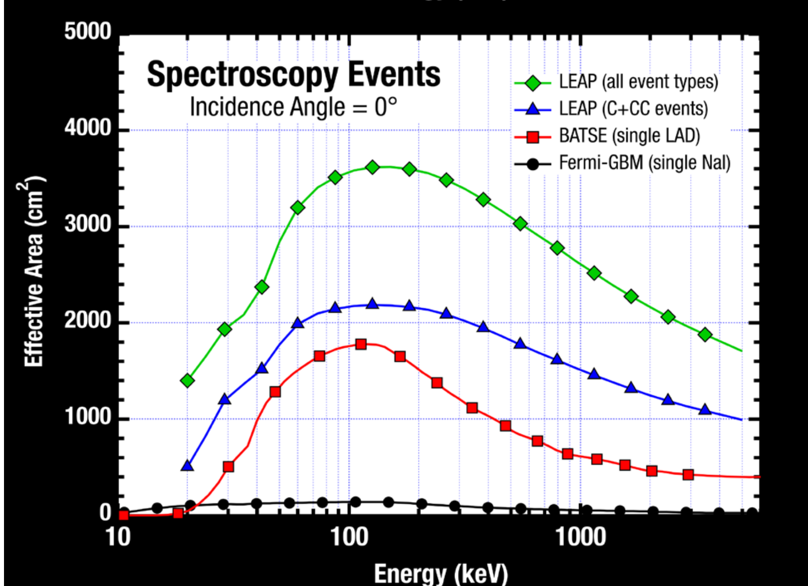


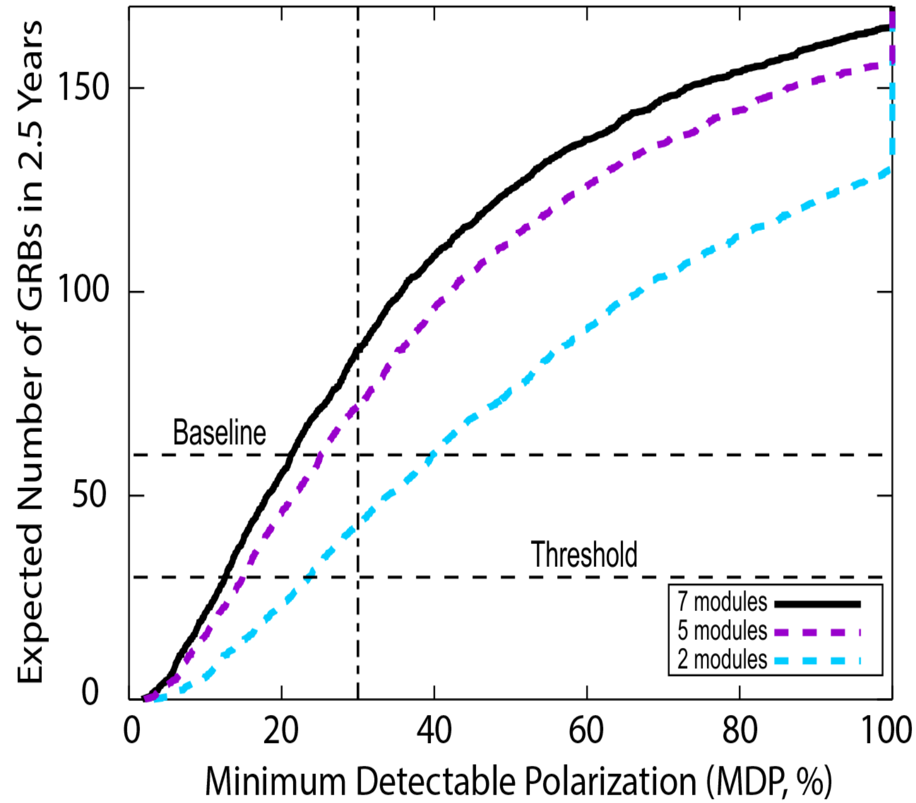
Minimum detectable polarization is well correlated with statistical localization uncertainty



LEAP Instrument Performance







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The Importance of LEAP

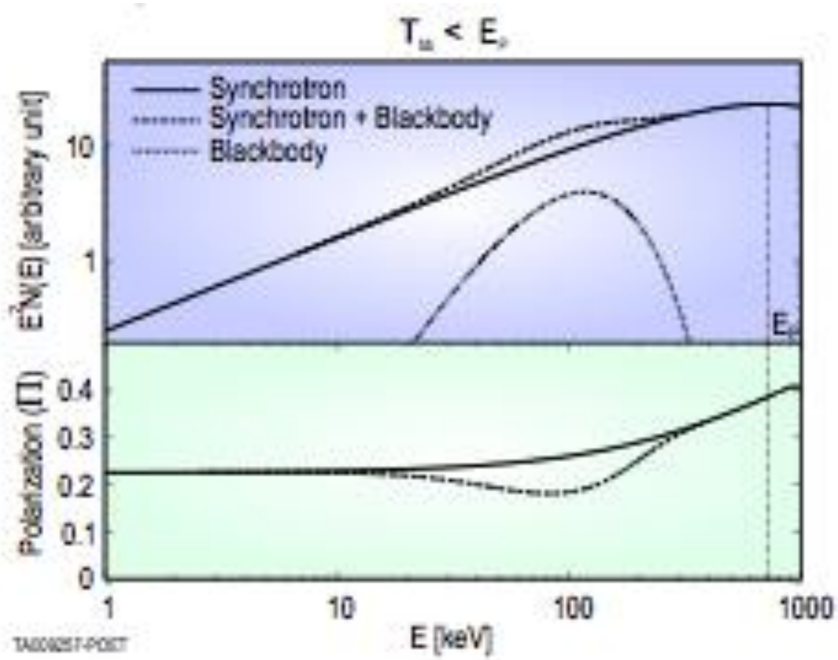
- Polarimetry is the next step towards our understanding of the GRB physics. Until now, studies have concentrated on time histories and spectra. Now is the time to move forward with polarimetry.

- Probing the central engine of GRBs provides insight into the nature of astrophysical jets, which are ubiquitous in the Universe.

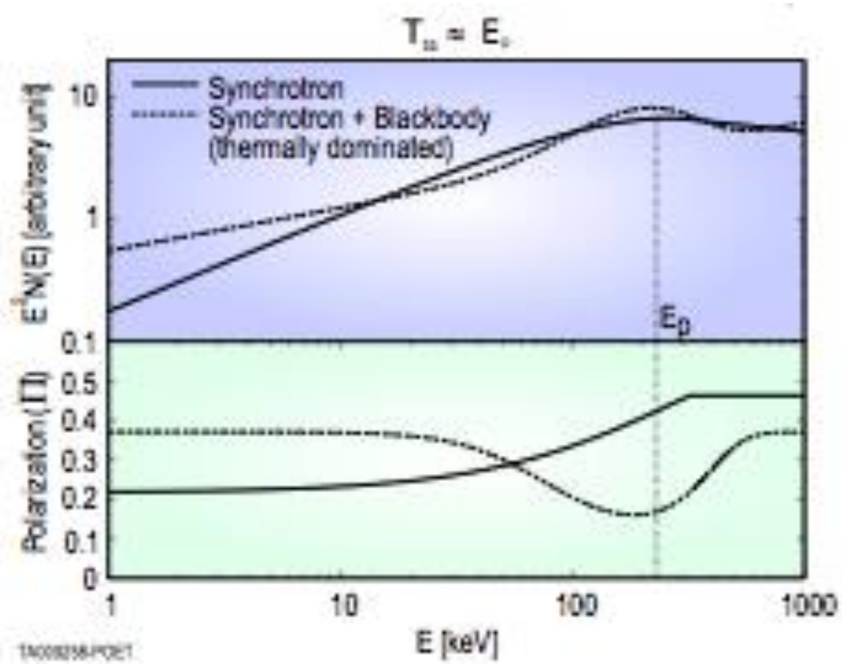
- LEAP will provide correlated measurements of GRBs with gravitational wave observatories at a time when Swift and/or Fermi may no longer be available.

Energy-Dependence of GRB Polarization

Different emission mechanisms predict a different dependence of polarization on energy. If the typical Band spectrum is synchrotron- dominated, E_P would correspond to a break in the non-thermal electron spectral distribution, with a characteristic change in Π near E_P.

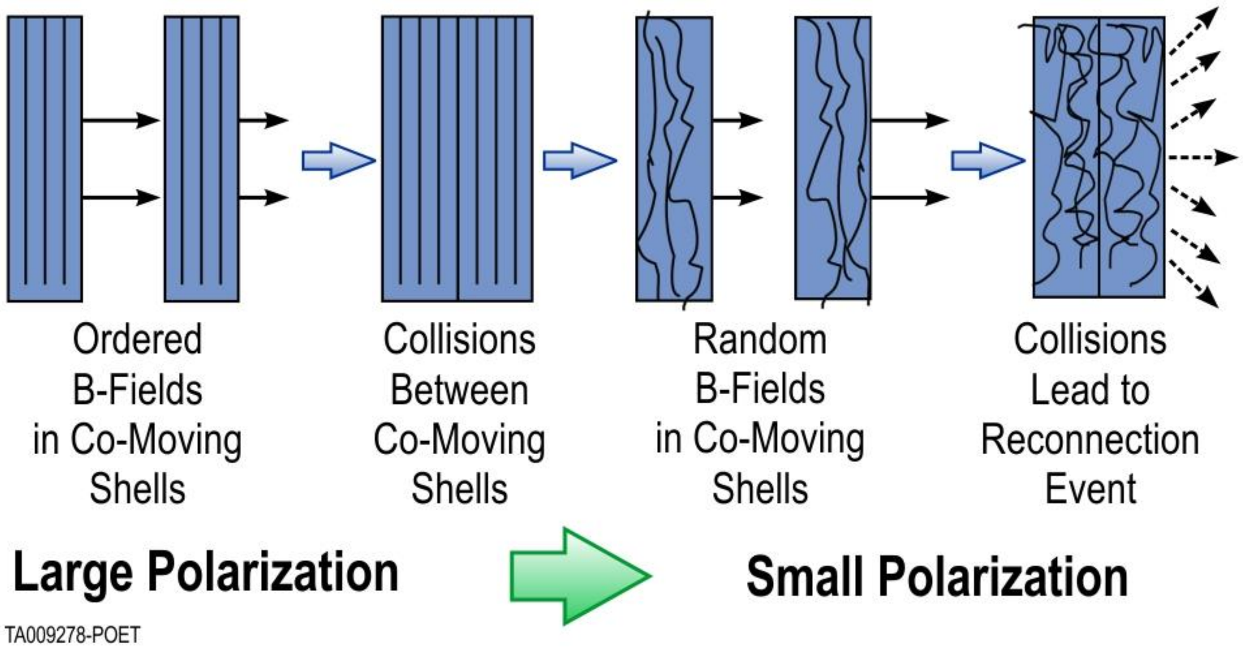


A simple blackbody component, seen in some GRBs, results in a reduction of P near the location of the blackbody peak.



A modified blackbody spectrum approximates the Band spectrum, but exhibits very different polarization properties.

Time-Dependence of GRB Polarization

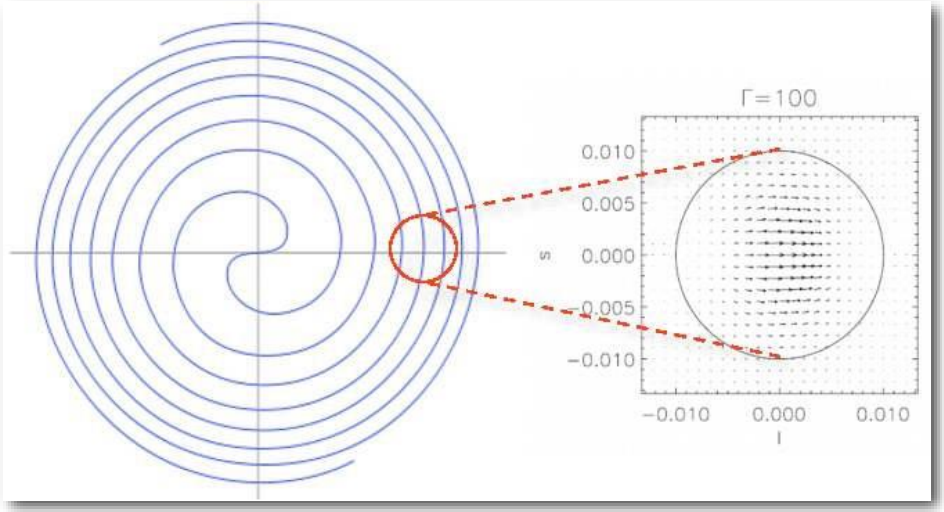


The ICMART model (Zhang and Yan, 2011) predicts that interacting shells within the outflowing jet will lead to increasingly random magnetic field structures that eventually produce reconnection events.

Toroidal Magnetic Field Model

In the canonical view of a twisted magnetic field within the jet, the magnetic field is largely toroidal.

If observer sees the whole jet, polarization will average out to zero.



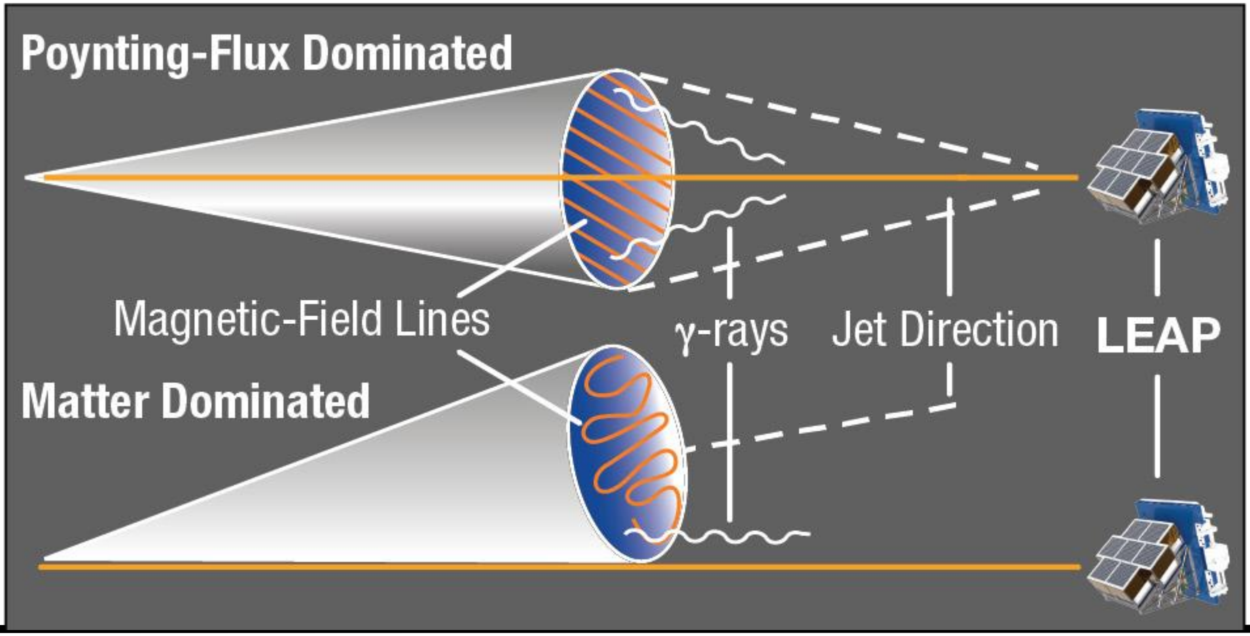
In a relativistic jet, the observers sees only a fraction of the total cross section, where the net polarization may be positive.

This model predicts large levels of polarization in almost all GRBs.

Importance of Viewing Angle

The viewing angle between the jet and the observer can also influence the degree of polarization.

A randomly oriented B-field structure may not average out the polarization signal if seen from off-axis.



Modified from Waxman, Nature, 423, 388 (2003)